Development and validation of the School Clinical Rugby Measure (SCRuM) test battery: Understanding the qualities or skills defining good male adolescent rugby union players

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Abstract

Background: Globally, the number of schoolboy adolescents playing highly competitive rugby is increasing even in countries such as Zimbabwe hardly known for dominating international rugby events. Given the increased participation rates, burgeoning talent identification and recruitment programs and the reportedly high injury risk associated with competitive youth rugby in Zimbabwe and globally, the minimal qualities or skills defining good male adolescent rugby players need further clarification. This study assembled a testing battery and compared the anthropometric variables, physiological characteristics and rugby-specific game skills of Zimbabwean schoolboys to identify qualities and/or skills discriminating elite from sub-elite male adolescent rugby players and non-rugby players within and between Under 16 (U16) and U19 age categories.

Methods: This study was structured in three phases. Phase I developed the School Clinical Rugby Measure (SCRuM) test battery based on amalgamated information derived from narrative literature review, qualitative study and two systematic reviews. Using mixed methods sequential explanatory study designs, Phase II refined the test battery through the evaluation of face and logical validity using key informants (n=5) and rugby experts (n=20), respectively. Subsequently, rugby coaches (n=30) assessed the practical feasibility of implementing each SCRuM test item in the local context considering test equipment, procedural and acceptability issues. Phase III evaluated the test-retest reliability of each SCRuM test item among a sample of elite U16s (n=41) and U19s (n=41). The final study in Phase III compared cross-sectional test performances of 208 athletes from different playing standards and age category to identify SCRuM test items discriminating (i) older (U19) players from younger (U16) players regardless of playing standards, and (ii) elite from both sub-elite and non-rugby players regardless of age.

Results: Phase I produced the first version of the SCRuM test battery with 23 variables. Phase II reduced the constituent components to 15 variables. The test-retest reliability study showed high intra-class correlation coefficient (ICC>0.70) for all SCRuM test items except for the 5-m, 10-m speed tests and passing-for-accuracy test. Age category had a significant main effect on all SCRuM test items except for sum of seven skinfolds ($p=0.45$, $\eta^2p=0.003$). Playing standard had a significant main effect on all variables except for height (p=0.40, η^2p=0.01) and sum of seven skinfolds (p=0.11, η^2p =0.02). Upper-and-lower body muscular strength and power, prolonged high-intensity intermittent running ability, repeated high-intensity exercise performance ability, tackling, passing and catching significantly improved with increasing playing standards. However, the Yo-Yo intermittent recovery level 1 test, vertical jump test, tackling proficiency test and running-and-catching ability skills test demonstrated greater discriminative ability across playing standards among U16s. The 40-m speed test, 2-kg medicine ball chest throw test, repeated high-intensity exercise test, one-repetition maximum bench press and back squat tests, and passing ability skills test showed better discriminative validity for differentiating U19s by playing standards.

Conclusion: Irrespective of playing standard and consistent with previous studies, all SCRuM test items significantly increased with age except for skinfolds measures. These results highlight the sensitivity of component SCRuM test items in discriminating younger (U16s) from older (U19s) athletes. U16 coaches should consider these differences when designing training interventions to assist with the development of prospective U19 players. However, prolonged high-intensity intermittent running ability, lower-body muscular power, tackling proficiency and running-and-catching ability demonstrated greater discriminative ability among U16s only, indicating a possible link to higher playing standards for that age category. Upper-body muscular power, upper-and-lower-body muscular strength, 40-m sprinting ability, repeated high-intensity exercise performance ability, and passing ability significantly improved with playing standards among U19s, highlighting the physiological characteristics and game skills capable of differentiating elite male adolescent rugby players from both sub-elite or non-rugby players at that age category. Collectively, these findings provide insight to the high school rugby coaches into the qualities and skills contextually relevant for training for the attainment of higher playing standards in schoolboy rugby at distinct age categories.

Keywords: Physiological characteristics, anthropometrics, rugby-specific game skills, schoolboy rugby, adolescents, Zimbabwe.

Declaration

I, ***Matthew Chiwaridzo,*** hereby declare that the work on which this thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university. I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

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2. **Chiwaridzo M**, Oorschot S, Dambi JM, Ferguson GD, Bonney E, Mudawarima, Tadyanemhandu C, Smits-Engelsman BCM. A systematic review investigating measurement properties of physiological tests in rugby. *BMC Sports Science, Medicine and Rehabilitation*. 2017; 9: 24.
3. Oorschot S, **Chiwaridzo M**, Smits-Engelsman BCM. Psychometric evaluation of the game-specific skills in rugby. A systematic review. *BMJ Open Sport and Exercise Medicine*. 2017; 3(1): e000281.
4. **Chiwaridzo M**, Munambah N, Oorschot S, Magume D, Dambi JM, Ferguson GD, Smits-Engelsman BCM. Coaches' perceptions on qualities defining good adolescent rugby players and are important for player recruitment in talent identification programs: The SCRuM project. *BMC Research notes*. 2019; 12(1): 132.
5. **Chiwaridzo M**, Ferguson GD, Smits-Engelsman BCM. High-school adolescents' motivation to rugby participation and selection criteria for inclusion in school rugby teams: Coaches' perspective (The SCRuM Project). *BMC Research notes.* 2019; 12(1): 103.
6. **Chiwaridzo M**, Chandahwa D, Oorschot S, Dambi JM, Tadyanemhandu C, Ferguson GD, Smits-Engelsman BCM. Logical validation and evaluation of practical feasibility for the SCRuM (School Clinical Rugby Measure) test battery developed for young adolescent rugby players in a resource-constrained environment. *PloS One*. 2018; 13(11): e0207307.
7. **Chiwaridzo M**, Ferguson GD, Smits-Engelsman BCM. Anthropometric, physiological characteristics and rugby-specific game skills discriminating Zimbabwean Under-16 male adolescent rugby players by level of competition. *BMJ Open Sports and Exercise Medicine*. 2019; 5:e000576.
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9. **Chiwaridzo M**, Ferguson GD, Smits-Engelsman BCM. Anthropometric, physiological characteristics and rugby-specific game skills of schoolboy players of different age categories and playing standards. *BMC Sports Science, Medicine and Rehabilitation*. 2020: 12; 3

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Dedication

I dedicate this thesis to my lovely wife (Precious Chizanga-Chiwaridzo) for her enduring support and to my lovely and beautiful twin daughters, Nokutenda and Nokuvimba, and my son Matthew Junior.

-To God be the glory-

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1-RM BS	One-Repetition Maximum Back Squat
1-RM BP	One-Repetition Maximum Bench Press
2-kg MBCT	2-kg Medicine Ball Chest Throw
$30\text{-}15_{IFT}$	30-15 Intermittent Fitness Test
AFL	Australian Rules Football
AMHQ	Adolescent Medical Health Questionnaire
ANOVA	Analysis of Variance
APHV	Age at Peak Height Velocity
BL	Blood Lactate
BRF	Back Row Forward
B/W	Between
CESRL	Co-educational Schools Rugby League
CI	Confidence Interval
CINAHL	Cumulative Index of Nursing and Allied Health
CORR	Correlation
COSMIN	Consensus-based Standards for the Selection of health Measurement Instruments
CODS	Change of Direction Speed
CMJ	Countermovement Jump
CV	Coefficient of Variation
DIFF	Difference
DZSRF	Dairiboard Zimbabwe School Rugby Festival
ES	Effect Size
FRF	Front Row Forward
GPS	Global Positioning Systems
HI	High-Intensity
HIA	High-Intensity Activity
HIEP	High-Intensity Exercise Performance
HIRA	High-Intensity Running Ability
HPFPs	High Priority Feasibility Parameters
HR	Heart Rate
HREC	Human Research Ethics Committee
IB	Inside Back
ICC	Intraclass Correlation Coefficient
I-CVI	Item-Content Validity Index
IHSRL	Interscholastic High School Rugby League
IQR	Interquartile range
JS	Jump Squat
LI	Low Intensity
LIA	Low-Intensity Activities
LoA	Limits of agreement
LPFPs	Low Priority Feasibility Parameters
M	Mean
MI	Medium intensity
MPFPs	Medium Priority Feasibility Parameter
MT	Mental Toughness
MRCZ	Medical Research Council of Zimbabwe

MSFT	Multistage Fitness Test
NZ	New Zealand
OB	Outside Back
PAR-Q	Physical Activity Readiness Questionnaire
PCC	Pearson's Correlation Coefficient
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RAT	Reactive Agility Test
REA	Repeated Effort Ability
RHIE	Repeated High Intensity Exercise
RS^2	Rugby Specific Repeated Sprint Test
RSA	Repeated Sprinting Ability
RL	Rugby League
RU	Rugby Union
RWC	Rugby World Cup
SA	South Africa
SD	Standard deviation
SEM	Standard Error of Measurement
SESRL	Super Eight Schools Rugby League
SCRuM test battery	School Clinical Rugby Measure test battery
SIGN	Significant
SKF	Skinfolds
SPSS	Statistical Package for the Social Sciences
SR	Sit-and-Reach test
SRC	Sports and Recreation Commission
T120S	Triple 120m shuttle run test
TE	Typical error
TE%	Percent Typical error
TEM	Typical error of measurement
TID	Talent Identification
TFI	Test-Feasibility Index
TMA	Time Motion Analysis
U	Under
US	United States
VJ	Vertical Jump
W60s	Wingate 60s cycle test
WR	World Rugby
WSLS	Wall Sit Leg Strength
Yo-Yo IRT1	Yo-Yo Intermittent Recovery Level 1 Test
Yo-Yo IRT2	Yo-Yo Intermittent Recovery Level 2 Test
YPHV	Years from Peak Height Velocity
ZNRL	Zimbabwe National Rugby League
ZRU	Zimbabwe Rugby Union

1 CHAPTER 1: INTRODUCTION

1.1 Introduction

This chapter presents the background of a study conducted to determine the qualities and/or game skills defining “good” male adolescent rugby players. Briefly, this study entailed assembling the School Clinical Rugby Measure (SCRuM) test battery composed of anthropometric, physiological characteristics and rugby-specific game skills with the ultimate purpose of identifying test items capable of discriminating athletes of different playing standards and age categories. In addition, to understand the contextual background underpinning the study rationale, this chapter highlighted the challenges facing Zimbabwe rugby and the important connection between schoolboy and senior professional rugby.

1.2 Background and need

15-a-side rugby union (hereafter referred to as “rugby” and abbreviated as “RU”) is a contact team sport played by over 8.5 million people in more than 120 countries including Zimbabwe [1]. Since becoming a professional sport in 1995, RU has undergone tremendous changes both on and off the pitch [2-8]. Increased professionalism has changed the landscape and global spread of rugby, including also the game rules, spectator popularity, player remuneration, player numbers, fitness characteristics and match demands [5, 9-17]. Today, rugby match demands have increased considerably with elite senior players worldwide competing in a greater number of club, national, and international rugby games compared to two decades ago [10, 16, 18-24].

Due to the increased competition demands and need for sporting success at an elite senior level, calls for a greater pool of talented rugby players have been made [20]. Presently, professional RU clubs and national rugby governing bodies worldwide are investing in talent identification (TID) initiatives and long-term junior development programmes aimed at early training of young players [20, 25-29]. Partly, these efforts have contributed to an increased number of junior players specialising and playing competitive rugby in organised settings such as schools or academies worldwide [27, 30-33].

Today, rugby is a popular sport among male adolescents. For example, there are over 700 000 rugby participants in Australia with the majority reported to be school-based adolescents [34]. England boasts of higher adolescent participation rates in rugby than any other country worldwide [25, 35]. In the United States (US), almost half of the total registered rugby players are reported to be male adolescents [36]. About 500 000 were distinguished as junior schoolboy rugby players playing in the Under 7 (U7) to Under 19 (U19) age categories in South Africa (SA) [37]. With decreased participation rates compared to the figures reported for Australia, England, US and SA, there are over 38 000 rugby players in Zimbabwe, with the majority being reported as schoolboy male adolescents playing at different levels of competition [38-40].

Although participation in sports is laudable because of the associated positive health benefits [41, 42], the number of school-children playing highly competitive rugby is of significant concern [43, 44]. The adolescence period represent a key transitional stage of human development characterised by accelerated physical growth, biological maturity and psychological development. As such, legitimate concerns have been raised by coaches, parents and researchers cognisant of the collision and combative nature of the sport [45], increased competitive match volumes [46, 47], insufficient or excessive training exposures [48] and greater probability of catastrophic injuries compared to other school-based sports such as soccer or cricket [37, 49, 50, 51-60]. Also, variations in biological maturity and physical sizes are common among same-aged adolescent schoolboy rugby players and have been linked to greater injury risk [32, 61, 62]. Additionally, training and match physical demands associated with higher levels of competition for junior rugby are increasingly becoming more adult-like against the backdrop of an immature skeletal system for young athletes [32, 63-69]. With all this in mind, research studies examining the attributes of male adolescents involved in highly competitive (elite) rugby are continuously warranted. Most importantly, studies comparing adolescent rugby players of different playing standards and age category become pertinent in understanding the ideal attributes in need of training. This is particularly so for countries such as Zimbabwe where competitive schoolboy rugby is an emerging phenomenon and has been gaining unparalleled attention lately [30].

Although conflicting, existing evidence on the attributes of schoolboy RU players linked to higher playing standards has emanated largely from top rugby-playing countries such as Australia, England or SA [25, 27, 29, 32]. To the best of the authors' knowledge, no such studies have been conducted in resource-constrained countries hardly known for dominating international rugby competitions such as Zimbabwe. This knowledge gap is rather unfortunate as such information has contextual implications on designing specific training practices possibly enhancing the quality of the schoolboy playing population in Zimbabwe. It is possible that differences in lifestyle, socio-economic status, playing standards and styles, training-related factors, and player recruitment strategies among other factors may limit direct extrapolation of results from studies conducted in other countries. Evidence from other countries is thus unlikely to inform training interventions that contribute to the attainment of elite status among schoolboy rugby players in Zimbabwe.

1.2.1 Zimbabwe rugby: contextual information

Rugby commands a sizeable participant and spectator base at senior and junior levels in Zimbabwe [30, 38-40]. As of May 2019, Zimbabwe was ranked 37 in the world [70], partly reflecting the state of rugby affairs in the country. As reported in the print media, the last two decades have seen a general deterioration in the state and administration of the sport at the senior professional level. Briefly, the decline has been characterised by:

i. Constant failures to qualify for Rugby World Cup (RWC) since 1991, coupled with a string of poor results against African rugby "giants" such as Uganda, Namibia, and Kenya in the Rugby Africa Gold Cup competition [71-73].

ii. Temporary suspension of the national rugby governing body, the Zimbabwe Rugby Union (ZRU), by the Sports and Recreation Commission (SRC) in 2017 due to internal squabbles [71, 74].

iii. Postponement of the Zimbabwe National Rugby League (ZNRL) since 2014 due to financial challenges [75].

iv. Inadequate local and external investment into rugby development due to deteriorating economic and political environment in the country [76, 77].

Notwithstanding these challenges, rugby is growing in popularity among schoolboy participants. This is because rugby is offered as an extra-curricular sport in many schools countrywide [30]. However, in a bid to promote and strengthen junior rugby in high schools, the Ministry of Primary and Secondary Education in collaboration with ZRU established two corporate-sponsored school-based rugby leagues, namely the Super Eight Schools Rugby League (SESRL) and Co-Educational Schools Rugby League (CESRL) [78]. The "elite" SESRL features eight most competitive rugby-playing government (n=2) and private (n=6) high schools across the country [30]. This league runs parallel with the CESRL, representing the second most competitive schoolboy league (sub-elite) featuring eight (8) private schools from around the country. All the SESRL schools have a local reputation for having a strong and long-standing culture of playing highly competitive rugby. In addition, the SESRL schools boast of a large pool of schoolboys to select from by virtue being unisex boys schools compared to CESRL schools which have a mix of both gender. The schools in the SESRL and CESRL variably expose U13 to U19 rugby players to an optimal environment for learning and practising rugby. This is done through the provision of superior coaching services, excellent training facilities, adequate training resources, early specialisation, selective scholarships, medical and physiotherapeutic services, and exposure to regional or international schoolboy rugby events. Annually, these leagues produce U19 players capable of joining adult professional clubs with potential to represent the country in future. However, the rest of other schools compete in various amateur inter-scholastic high school rugby leagues (IHSRLs) with schools in the same educational district mainly for recreational purposes.

The existence of well-organised schoolboy rugby plays an important role in ensuring the survival of Zimbabwe rugby. In the absence of a functional junior rugby academy system and sustainable, objective national TID initiatives, schoolboy rugby forms the bedrock of junior rugby development in Zimbabwe. It dually acts as a national "reservoir" of potential junior rugby talent and a "conveyer-belt" of skilled young players ready for further sporting development at professional senior clubs. The Figure 1-1 below summarises the possible trajectories for young Zimbabwean rugby players after leaving high school.

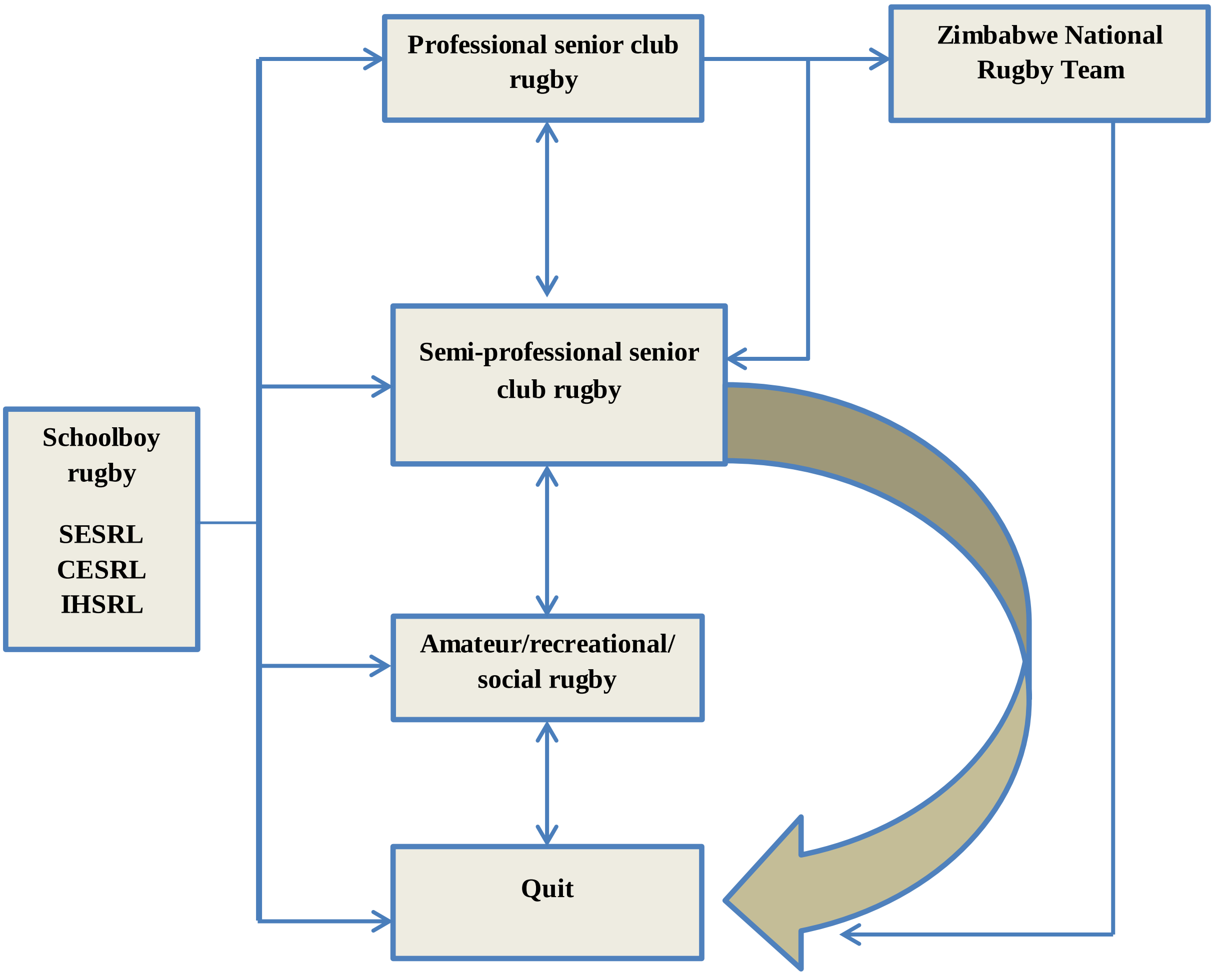


Figure 1-1: Possible trajectories for Zimbabwean junior players

There are several Zimbabwean-born rugby players who have successfully reached the top echelons of professional stardom from schoolboy rugby. These include, but are not limited to, Tendai Mtawarira (current SA national rugby player and 2019 RWC winner), Tonderai Chavhanga (former SA national rugby player), Takudzwa Ngwenya (former US national rugby player), Kennedy Tsimba (former SA national rugby player) and Brian Mujati (former SA national player). These players and others are a testament to the importance of schoolboy rugby to overall rugby development in Zimbabwe and even beyond.

The potential role of schoolboy rugby in stimulating growth and development of Zimbabwe rugby, in general, has inspired interest from multiple stakeholders such as corporate sponsors, professional senior RU clubs, and sports scientists. For instance, Old Mutual Zimbabwe, a corporate entity, is spearheading junior rugby development programmes providing largely the financial versatility needed for such programmes [79]. To complement such efforts, some professional rugby clubs assist by adopting schools in the SESRL and CESRL providing technical and financial support. In return, professional clubs acquire young talented rugby players from the adopted schools upon school completion. These reciprocal relationships play an important developmental role in ensuring continuity in playing rugby for scouted players. Moreover, in support of the local endeavours to promote junior rugby in Zimbabwe, it is imperative for sports scientists to investigate several issues of perceived importance to the survival, development of schoolboy rugby and eventual production of competent junior players. Briefly, some of the perceived factors are, but are not limited to:

i. The reasons influencing schoolboys' participation in highly competitive rugby

It is important to understand specific reasons motivating schoolboys to play competitive rugby. Understanding the motivating factors may inform the development and implementation of contextual strategies, spearheaded by coaches, aimed at increasing participation rates among schoolboys. This would ensure the survival of junior rugby developmental pathways and guarantee an increased pool of young rugby players. Currently, in school settings, rugby seems to be an "elite" sport played competitively only by top public and private schools in the SESRL and CESRL. It is, however, unclear what specifically motivates schoolchildren in these schools to participate in a sport well known for its collision and combative nature.

ii. The selection criteria used by high school rugby coaches for player selection

The Ministry of Primary and Secondary Education in Zimbabwe mandates every learner to engage in physical education or sport of choice [30]. Consequently, many schoolchildren participate in single or multiple sports for recreational and competitive purposes. Given the possibility of schoolchildren joining any sport of choice, it is important then to understand strategies used by coaches when selecting schoolchildren for inclusion into school rugby teams for SESRL or CESRL competitions. This information potentially informs on the important attributes valued by schoolboy rugby coaches especially for team selection and would assist in test battery design.

iii. *Identification of key qualities and/or skills defining "good" male adolescent rugby players*

This contextually and objectively informs schoolboy rugby coaches on specific attributes requiring training. Once these attributes are known and trained long-term, this ensures a greater pool of competent junior players likely to transition to senior professional rugby with the requisite skills and qualities. Currently, there is a dearth of information on whether Zimbabwean schoolboys involved in highly competitive rugby possess the appropriate qualities or skills. Additionally, there is a paucity of information on the specific attributes discriminating players in the "elite" SESRL from the "sub-elite" CESRL. Given that SESRL and CESRL are the two most competitive schoolboy rugby leagues in Zimbabwe, a comparison of qualities or skills of players in the respective leagues would facilitate understanding of the basis of SESRL players' superiority. Furthermore, a comparison between schoolboy rugby players with age-matched players playing a different sport such as cricket, known to have physical and technical demands opposed to rugby [80], may also hint on the general qualities or skills ideal for schoolboy rugby. Figure 1-2 below further illustrates additional general factors perceived as critical in junior rugby development. However, in an attempt to understand the qualities or skills defining good male adolescent rugby players, this thesis narrowly focuses on the role of physical or physiological characteristics and rugby-specific game skills in distinguishing players of different playing abilities and age category using an assembled test battery.

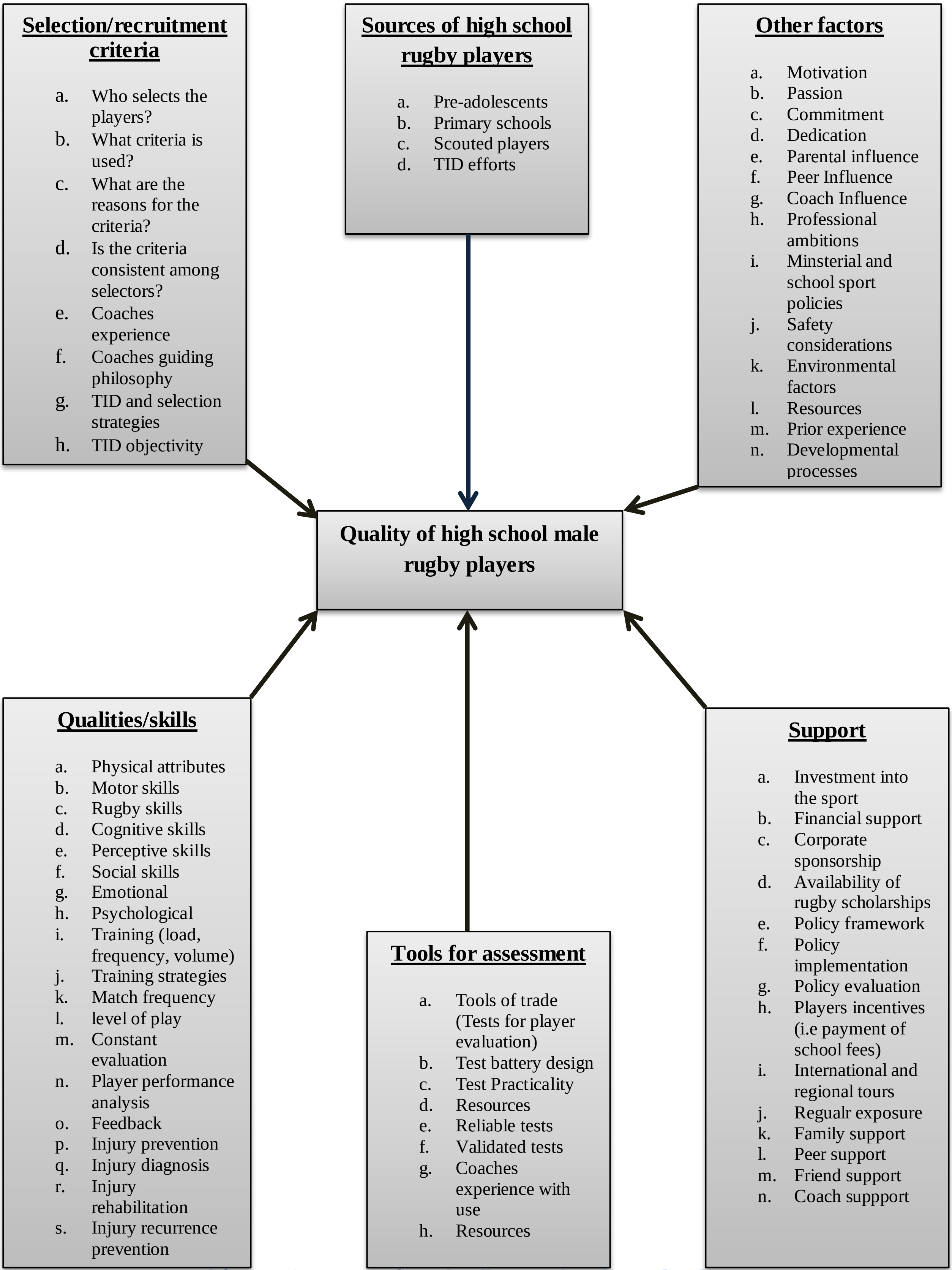


Figure 1-2: Contextual factors important for schoolboy rugby player development

1.2.2 Previous test batteries and rationale for test battery design

To enable the identification of attributes needed by rugby players, utilisation of test batteries is crucial [81]. Arguably, adopting or assembling a test battery design should be the first step towards a realistic and objective assessment of players' fitness characteristics and skills. However, the greatest challenge in the current literature is the lack of consensus among authors on the variables and corresponding tests to include in test batteries profiling junior rugby players. Consequently, there are many test batteries available in the literature with heterogeneous compositions. For example, Durandt et al [29] profiled 174 young RU players assessing height, body mass, seven-site skinfolds, speed, agility, upper body muscular strength-endurance, and aerobic fitness. In another study, Darrall-Jones et al [82] assessed height, body mass, eight-site skinfolds, speed, agility, lower-body muscular power, prolonged high-intensity intermittent running ability, anaerobic capacity, and upper-and-lower muscular strength. Although the authors assessed anthropometric and physiological characteristics highlighting the relevance of these constructs in adolescent rugby, the test batteries, however, differed on certain constituent variables. Darrall-Jones et al [82] included tests for lower-body muscular strength, power and anaerobic capacity unlike Durandt et al [29] who included upper-body muscular strength measures. Such differences, potentially, generate debate regarding the variables most relevant for the assessment of adolescent rugby players and which variables warrants possible inclusion in test batteries designed for player profiling.

Additionally, the use of different tests when assessing similar constructs is also prevalent. For instance, Durandt et al [29] measured agility using the Illinois agility test whilst Darrall-Jones et al [82] utilised the Agility 5-0-5 test. Also, the speed tests largely differed in split distances and test procedures. Darrall-Jones et al [82] used 5-m, 10-m, 20-m, and 40-m sprints with participants starting 0.5m behind the initial timing gate. However, Durandt et al [29] assessed sprints at 10-m and 40-m distances with players starting 0.3m from the start line. These inconsistencies in test selection and procedures render possible comparison between studies difficult [83] and questions test selection criteria when assembling test batteries for profiling adolescent rugby players.

Some authors rarely justify variable inclusion and corresponding test selection in developed test batteries. For example, the rationale for the choice of the agility tests used in Durandt et al [29] and Darrell-Jones et al [82] studies was elusive considering the wide range of tests available for measuring agility [84]. Also, authors inconsistently provide evidence of the measurement properties of selected tests. Unlike Durandt et al [29], Darrall-Jones et al [82] reported the intraclass correlation coefficient (ICC) and coefficient of variation (CV) for the Agility 5-0-5 test as evidence of relative and absolute test-retest reliability. It is generally reported that test selection must depend on display of acceptable measurement properties [85] and that evidence should be reported in the content of published articles for better interpretation of test results and to inform test selection for future authors [86]. Also, any other reason for test selection such as practical feasibility, common usage in the literature or local context should be mentioned in the content of published articles for better understanding the rationale for test inclusion.

Pienaar et al [87] compiled a test battery for male SA adolescent rugby players. The authors are credited for assembling the first test battery composed of rugby-specific game skills [81]. Since development, several authors have utilised the test battery with minor or no adaptations to content [88-90]. The strength of Pienaar et al [87] test battery and those of adopting authors was multi-dimensionality. The test batteries included a wide range of attributes from anthropometric, physical, motor, physiological characteristics and rugby-specific game skills which have documented relevance in rugby [87]. However, the rationale for the inclusion of the test items was seldom provided in the content of the articles. Moreover, several variables which would have given adequate logical validity to the test batteries designed for profiling anthropometric, physical, physiological abilities and rugby-specific skills of young players were not included. The test batteries excluded tests for tackling, repeated high-intensity exercise ability, repeated sprint and effort ability, aerobic fitness, anaerobic capacity and lower-body muscular strength and power which, ostensibly, relate to the intermittent and physical nature of the sport. Furthermore, although the included game skills seemed relevant for rugby, the corresponding tests could be criticised for lack of ecological validity since there were developed premised on the locomotor patterns of a different sport and were also assessed as closed skills [81]. Therefore, in the absence of a universally agreed test battery for profiling schoolboy rugby players, it is understandable that test batteries for the identification of qualities or skills important in schoolboy rugby should, at least, include test items that logically and comprehensively reflect match play of adolescent rugby. Test batteries logically-validated to the needs of young rugby players and further containing practically feasible and reliable tests are more likely to be suitable for use in discriminative validity studies.

1.2.2.1 Conceptual basis for variable inclusion in test battery design

Profiling rugby players should involve an objective assessment of the key requirements of the sport utilising standardised test batteries [26, 91]. This implies that it is the requirements of the sport of rugby which should provide a conceptual framework underpinning the selection of component variables during test battery development. However, to understand the key qualities or skills needed in rugby and the variables for inclusion in test batteries, knowledge of the match demands of rugby is essential. This knowledge helps in understanding locomotor and non-locomotor activities common in rugby [69, 92] and, consequently, facilitates the development of test batteries that replicate these patterns or has test items that capture the essence of expertise within the sport [28]. Theoretically, test batteries designed for male adolescent rugby players should comprehensively reflect, in variable composition, the physical and technical match demands of the sport.

Alternative approaches to understanding variables for inclusion in test batteries involves establishing either qualities or skills with greater discriminative ability of differentiating rugby players by playing standards or identifying player attributes related to successful match performances [93]. These variables are likely to indicate important attributes required in rugby. However, the literature on adolescent rugby is inconclusive on the specific qualities and/or skills capable of differentiating schoolboy RU players by playing standards. With the wide range of variables and tests incorporated in test batteries used in previous studies, results have varied between studies, countries and age categories as a consequence. For example, Jones et al [25] found that body mass, upper-body muscular strength and 10-m running momentum, effectively discriminated higher-level U18 academy RU players from lower-level U18 schoolboy rugby players in England. However, aerobic fitness, speed and height failed to differentiate these rugby players. In another study, Spamer et al [94] found that elite U16 NZ male players representing higher-level players outperformed elite U16 SA male players for body mass, upper-body muscular endurance, lower-body muscular power, flexibility, 10-m speed, agility, air-and-ground skills, and passing-for-distance. However, no significant differences were observed for height, speed endurance, passing-for-accuracy, and kicking-for-distance between groups. Altogether, these findings highlight the possible influence of contextual or environmental factors, age, and playing standards on the discriminative capabilities of anthropometric, physiological and game skill variables.

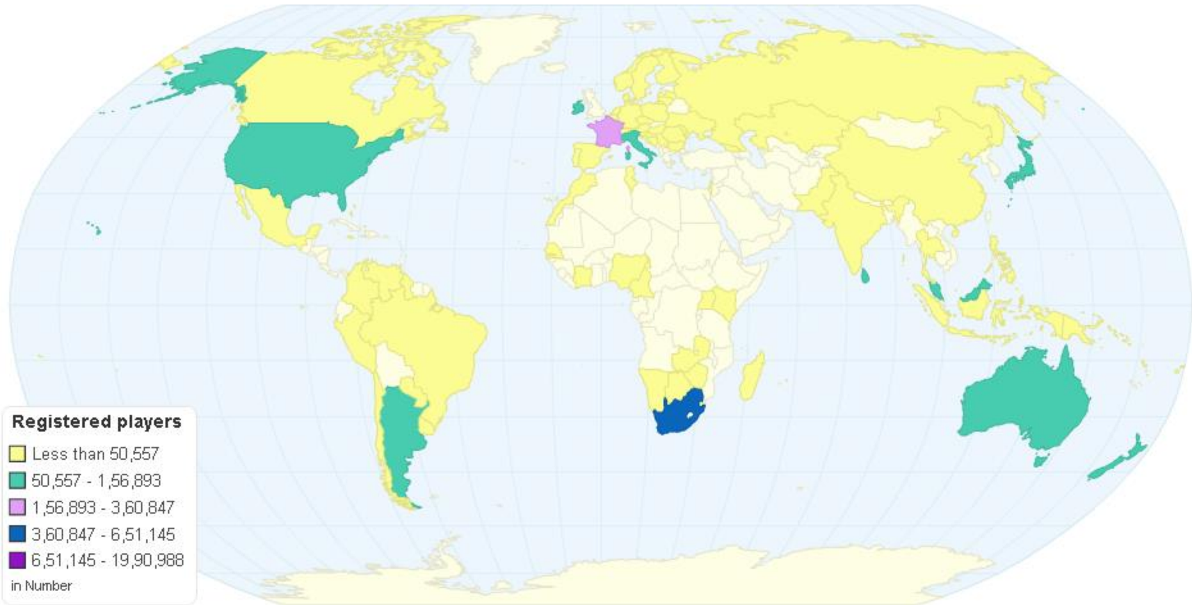
Furthermore, detailed information about RU in terms of how it is played, match duration, match rules and player positions provide additional insight into the possible attributes key to the sport of rugby and in need of consideration during test battery design. Additionally, determination of commonly evaluated qualities or skills and their corresponding tests from literature broadens our understanding of the most important attributes assessed in rugby and frequently used methods of measurement. There is empirical evidence suggesting that playing styles differ between rugby teams and, most importantly, between countries (southern hemisphere *vs*. northern hemisphere) largely influencing coaches training and player selection strategies [22]. Hence, coaches' perceptions of the qualities or skills defining talented rugby players and player selection strategies used by coaches may also assist with understanding of the attributes which reflects expertise in rugby and need consideration in test battery design.

All the above-mentioned guiding points ensure that developed test batteries have all the relevant variables or attributes related to rugby performance important for inclusion in a test battery designed for profiling rugby players [81]. Once assembled, the test battery may be evaluated for face, logical/content validity, practical feasibility, and reliability using explanatory sequential mixed-methods experimental designs. Subsequently, known-group validity analyses may be employed to evaluate the ability of the component test items to discriminate between two or more groups known to differ on variables of interest [28]. This allows identification of the rugby-relevant qualities or skills defining good players.

1.3 Problem statement

1.3.1 Theoretical perspective to the problem

Although RU is growing in popularity among junior players worldwide, few studies have documented the evidence of anthropometric, physiological characteristics and rugby-specific game skills linked to higher playing standards for schoolboy players [20, 25, 29, 82, 87, 90, 95]. Almost all the existing evidence is from high and upper middle-income countries with well-established junior RU developmental pathways and increased participation figures (Figure 1-3). There is a paucity of studies from low-resource countries such as Zimbabwe with emergent competitive schoolboy rugby. Given differences between high and low-income rugby-playing countries in terms of socio-economic status, lifestyle, playing standards, TID initiatives among other factors which may have a significant impact on players attribute development, it is unclear if the qualities and/or skills linked to higher playing standards among Zimbabwean schoolboy rugby players are similar or different to those reported in high and upper middle-income countries.



(Acknowledgement of source: Internet. Google.URL: **http://chartsbin.com/view/42777**)

Figure 1-3: Rugby playing countries

Most adolescent RU studies available in the literature have compared groups of only elite male adolescent players that are vastly different in playing standards. For example, there is evidence on the qualities and/or skills differentiating age-matched elite male adolescent RU players from different countries representing different playing standards [94, 96, 97]. Generally, results from these studies showed that anthropometric, physiological characteristics and rugby-specific game skills improved with increasing playing standards [98]. However, in such studies, the link between anthropometric, physiological and rugby-specific game skills and higher playing standards may be overstated because of possible large contextual differences in lifestyle, socio-economic status or environmental factors between countries [96].

Also, there is evidence on qualities and/or skills of only elite male adolescent RU players playing at different age categories [29, 82, 89, 90]. Generally, these studies showed that anthropometric (except skinfold), physiological characteristics and skill ratings improve with age. Although these findings highlight the primary influence of age or maturity-related factors in attribute development among elite rugby players, a limitation of such studies has been the lack of a control group (either sub-elite group or non-rugby group or both) for comparison purposes. Inclusion of comparative groups facilitates understanding of the influence of playing standard on cross-sectional test performances between age categories (for example, U16 *vs*. U19). In such cases, the magnitude of test performance differences between age categories may also be compared across playing standards (for example, elite group *vs*. sub-elite group *vs*. non-rugby group). To the best of authors' knowledge, no study has specifically compared elite schoolboy RU players with sub-elite schoolboy RU players and competitive non-rugby players between and within specific age categories in the literature. Such studies provide additional information on the specific attributes important for the attainment of elite status by sub-elite rugby players and, further, inform on the general qualities or skills needed by non-rugby players for participation in rugby. At a school-setting, this information creates a strong foundation for launching targeted training interventions and talent selection initiatives sensitive to the playing abilities of potential players. Also, it is unclear if the differences in anthropometrical and test performances between age categories are similar or different across different playing standards. Cognisant of the practical challenges with longitudinal study designs, such studies inform on the magnitude of cross-sectional differences secondary to adaptations to training or age-related factors across playing standards.

Several adolescent RU studies have evaluated the independent effects of age category [29, 82, 90, 89] or playing standard [25, 94, 96, 87, 97] on player performances. However, young athletes' test performances are likely to reflect the combined effects of age and playing standard. This is suggestive of an interactive effect of growth-and-maturity related factors and training-related factors on player performances. There seem to be limited understanding in the current literature of the interactive effect of age and playing standard on junior rugby players cross-sectional test performances, information which has greater implications on understanding the relative influence of age on the discriminative abilities by playing standards for tests of anthropometrical, physiological characteristics and game skills.

1.3.2 Contextual perspective to the problem

The only pathway for junior (U13-U19) RU development in Zimbabwe is within the school system. With the recent establishment of SESRL and CESRL, competitive schoolboy rugby is steadily growing in popularity and has been linked to high injury risk among participants [30]. This is of concern given that participants are full-time learners playing highly competitive rugby as part of extra-curricular sporting activity. In both leagues, serious and highly competitive rugby commences at U16 up to U19 level. Conceivably, a subset of young players from both leagues will continue playing professional rugby into adulthood. Hence, schoolboy rugby forms the bedrock of Zimbabwe senior rugby as it continuously produces young players capable of embarking into professional rugby. It is unfortunate, however, that no study has documented the qualities and/or skills of schoolboys involved in competitive RU in Zimbabwe. Besides, no study has compared the qualities or skills of players in the SESRL and CESRL at the entry-level into serious competitive schoolboy rugby (U16 age category) and exit point (U19 age category) to determine attributes linked to higher playing standard between and within these age categories. Additionally, no study has also compared "elite" and "sub-elite" rugby players with "elite" non-rugby players playing a competitive sport opposed to rugby.

Hence, it is unclear whether "elite" SESRL school rugby players are distinguishable from "sub-elite" CESRL rugby players or whether both rugby groups are distinguishable from "elite" non-rugby players through anthropometric qualities, physiological characteristics and technical skills.

The paucity of information on specific qualities and/or skills defining good Zimbabwean male adolescent rugby players hampers effective contextual programmes aimed at objectively identifying, selecting and recruiting potential rugby players at U16 and U19 level. Also, lack of that information creates a vacuum for justifying specific training of physical characteristics and rugby-specific game skills among schoolboy rugby players for the attainment of "elite" status. Although Zimbabwean schoolboy rugby is no different from rest of the world in terms match play and rules, it is possible that differences between countries in lifestyle, socio-economic status, playing standard, and player recruitment and identification policies among other factors may limit direct extrapolation of data from other countries to inform specific training interventions in Zimbabwe schoolboy rugby.

1.4 Purpose of the study

This study aimed to compile a test battery with a wide range of anthropometric, physiological characteristics and rugby-specific game skills for the ultimate purpose of identifying component test items capable of discriminating elite SESRL rugby players from sub-elite CESRL and non-rugby players between and within U16 and U19 age categories. Therefore, this study was conducted to answer the following primary research questions.

1.5 Primary research questions

1. Which anthropometric variables, physiological characteristics and rugby-specific game skills discriminate older U19 male adolescent players from their younger U16s counterparts regardless of playing standard?
2. Which anthropometric variables, physiological characteristics and rugby-specific game skills discriminate elite SESRL male adolescent players from both sub-elite CESRL players and non-rugby counterparts regardless of age-category?

3. Assessing for a possible interaction between the effects of age and playing standards, are the discriminative capabilities across playing standards (elite *vs.* sub-elite *vs.* non-rugby) of tests for anthropometric variables, physiological characteristics and rugby-specific game skills age-dependent?

1.5.1 Secondary research questions

The following secondary questions were formulated to help answer the primary research questions:

1. Which qualities or skills and their corresponding tests should be included in the SCRuM test battery to assess the anthropometric, physiological characteristics, and rugby-specific game skills of schoolboy rugby players?
2. Following the assembling of the first version of the SCRuM test battery, which constituent variables and corresponding tests have:
   (i) Satisfactory face validity based on the ratings of key rugby informants.
   (ii) Acceptable content/logical validity based on the collective ratings of local and international rugby experts.
   (iii) High practical feasibility for possible implementation in the local setting based on the ratings of rugby coaches.
3. Which test items, included in the face-and-content validated and practically-feasible version of the SCRuM test battery, have acceptable absolute and high relative reliability coefficients when evaluated using repeated measures among a sample of U16 and U19 male adolescent rugby players?

1.6 Aims and objectives of the study

To answer both primary and secondary research questions, this study was structured in three sequential phases. Each phase had an overarching aim and was sub-divided into individual study parts.

1.7 Phase I: Development of the SCRuM test battery

Given the absence of a universally-agreed test battery for profiling schoolboy rugby players in the literature, the aim of Phase I was to develop the first version of the SCRuM test battery to reflect important anthropometric, physiological characteristics and game skills needed in rugby. The developmental process of assembling the test battery was informed by recommendations from literature [99-101]. To accomplish the development of the test battery, Phase I was divided into three sequential study parts.

1.7.1 Part 1: Narrative literature review

The broad objective of the narrative literature review was to present what is known about the key requirements of rugby. Specifically, the review involved:

i. A narrative synthesis of documented information describing how RU is played and the performance roles for the generic positions of forward and backline players, ultimately highlighting the implications of this information on the qualities or skills needed by rugby participants.
ii. A critical appraisal of RU studies to understand the physical, physiological, kinematic and technical demands of rugby, from studies utilising time-motion analysis (TMA), global positioning systems (GPS) and physiological indices such as heart rate values and blood lactate concentration levels.
iii. A narrative synthesis of selected studies presenting evidence on anthropometrical variables, physiological characteristics, and rugby-specific technical skills capable of differentiating rugby players of different playing abilities and/or age categories.

1.7.2 Part 2: Qualitative study

To further inform on the variables to be included in the test battery and augment theoretical evidence garnered in part 1, the broad objective of part 2 of Phase I was for in-depth exploration of the perceptions of schoolboy rugby coaches' on the qualities or skills defining "good" male adolescent rugby players and are important for player recruitment in talent identification and recruitment programmes. Secondarily, this part of the study explored reasons motivating high school male adolescents to participate in competitive rugby and explored strategies used by local rugby coaches when selecting high school male adolescents into school rugby teams.

1.7.3 Part 3: Systematic review

Following the identification of general qualities or skills important in rugby based on amalgamated evidence from literature and rugby coaches, part 3 of Phase I specifically aimed to identify the most commonly-evaluated physiological characteristics and rugby-specific game skills and the corresponding tests frequently used for the assessment of the identified constructs in the literature. Most importantly, the study aimed to critically appraise literature to present evidence on the psychometric or measurement properties of each of the identified tests for the assessment of physiological characteristics and game-specific skills in rugby and related intermittent contact team sports such as rugby league (RL).

1.8 Phase II: Refinement of the SCRuM test battery

With Phase I expected to lead to the development of the first version of the test battery through collective evidence gathered and synthesised from the narrative literature review, qualitative study and systematic review, the aim of Phase II was to refine the assembled SCRuM test battery to reflect relevant and practically feasible test items based on the ratings of key informants, local and international rugby experts and rugby coaches. To achieve that, Phase II was divided into three distinct study parts.

1.8.1 Part 1: Face validation of the SCRuM test battery

The broad objective of part 1 of Phase II was to determine the extent to which the first version of the SCRuM test battery “appeared” to have all component variables measuring pre-selected domain constructs of anthropometric qualities, physiological characteristics and rugby-specific game skills as judged by key informants.

1.8.2 Part 2: Logical/content validation of the SCRuM test battery

Continuing with the consultative process of refining the compiled test battery, the two-pronged broad objectives for the part 2 study of Phase II were to determine the relevance of each component variable included in the face-validated version of the SCRuM test battery and the comprehensiveness of the entire test battery in covering all relevant pre-selected constructs of anthropometric, physiological characteristics and rugby-specific game skills as judged by local and international rugby experts.

1.8.3 Part 3: Practical feasibility assessment of the SCRuM test battery

The broad objective of this study was for the possible end-users of the SCRuM (schoolboy rugby coaches) to judge the feasibility of practically implementing each of the test items in the SCRuM test battery in the local context considering the following pre-selected feasibility parameters from literature:

i. Test equipment issues (quantity, type, availability, accessibility, cost)
ii. Test procedural issues (procedure, possible modifications, duration, personnel needed, easy of scoring and interpreting test results)
iii. Test acceptability issues (perceived appropriateness, age-specificity, test safety concerns)

1.9 Phase III: Test-retest reliability and construct validity of SCRuM test battery

With Phase II ultimately producing a face-and-content validated SCRuM test battery composed of practically feasible test items, the main aim of Phase III was then to investigate the test-retest reliability and construct validity (known-group validity) of each of the SCRuM test items. As such, Phase III was divided into two study parts (preliminary study and main study) each with a separate broad objective.

1.9.1 Preliminary study

The broad objective of the preliminary study was to investigate the test-retest reliability for each test item in the SCRuM test battery among a selected sample of U16 and U19 male rugby players.

1.9.2 Main study

The broad objective of the main study was to investigate the ability of the test items in the face-and-content validated, practically feasible and reliable version of SCRuM test battery in discriminating groups of performers of different playing abilities and age categories. The following are three (3) major hypotheses to be tested in the main study and were formulated based on review findings of Till et al [98] and findings from isolated studies investigating game skills among adolescent RU players [87, 89, 90, 94, 96, 97].

i. Regardless of age-category, SCRuM test scores would improve with increasing playing standards (i.e. elite rugby players would significantly outperform both sub-elite rugby and non-rugby players, and concurrently, sub-elite rugby players would significantly outperform non-rugby players).

ii. Irrespective of playing standard, older (U19) players would have significantly higher SCRuM test item scores compared to younger (U16) players except for skinfolds measurement.

iii. There would be significant interactions between the effects of age group (U19 *vs*. U16) and playing standards (elite *vs*. sub-elite *vs*. non-rugby) on anthropometrical and test performances.

1.10 Significance of the study

The results of this study will facilitate dual understanding of general attributes needed for rugby by non-rugby players and specific attributes needed for the attainment of elite status by sub-elite rugby players. Qualities or skills discriminating elite from sub-elite rugby players could be foci points for long-term junior rugby training and development programmes ensuring the attainment of elite status by sub-elite players. These results may also hint to junior rugby coaches on the qualities or skills possibly important for team or squad selection, and sports physiotherapists working with school rugby teams during the designing of rehabilitation intervention and training programmes following injury.

Additionally, in the absence of sustainable, objective and national talent identification initiatives in Zimbabwe, qualities or skills discriminating sub-elite from non-rugby players may hint to schoolboy rugby coaches, recruiters, and scouts on the important variables to emphasise during contextual talent selection and recruitment initiatives of potential U16 or U19 rugby talent. Furthermore, qualities or skills discriminant of developmental level (U16 *vs*. U19) may assist head coaches in designing tailored training interventions aimed at improving deficient characteristics and skills at the respective age category. This may assist with smoother U16 to U19 transition for the adolescent rugby players and understanding the unique combination of qualities or skills required for effective performance across each developmental level.

1.11 Structure of the thesis

To answer the primary and secondary research questions, this thesis was structured in nine chapters (Figure 1-4). As shown in Figure 1.4, the net result is the development of a test battery for use in a clearly defined rugby population in Zimbabwe based on six iterations or refinements, driven and informed by a wide range of suitable methodologies and research paradigms. Each chapter was designed to serve a specific and delineated purpose contributing to the fulfilment of the overarching aim of the thesis.

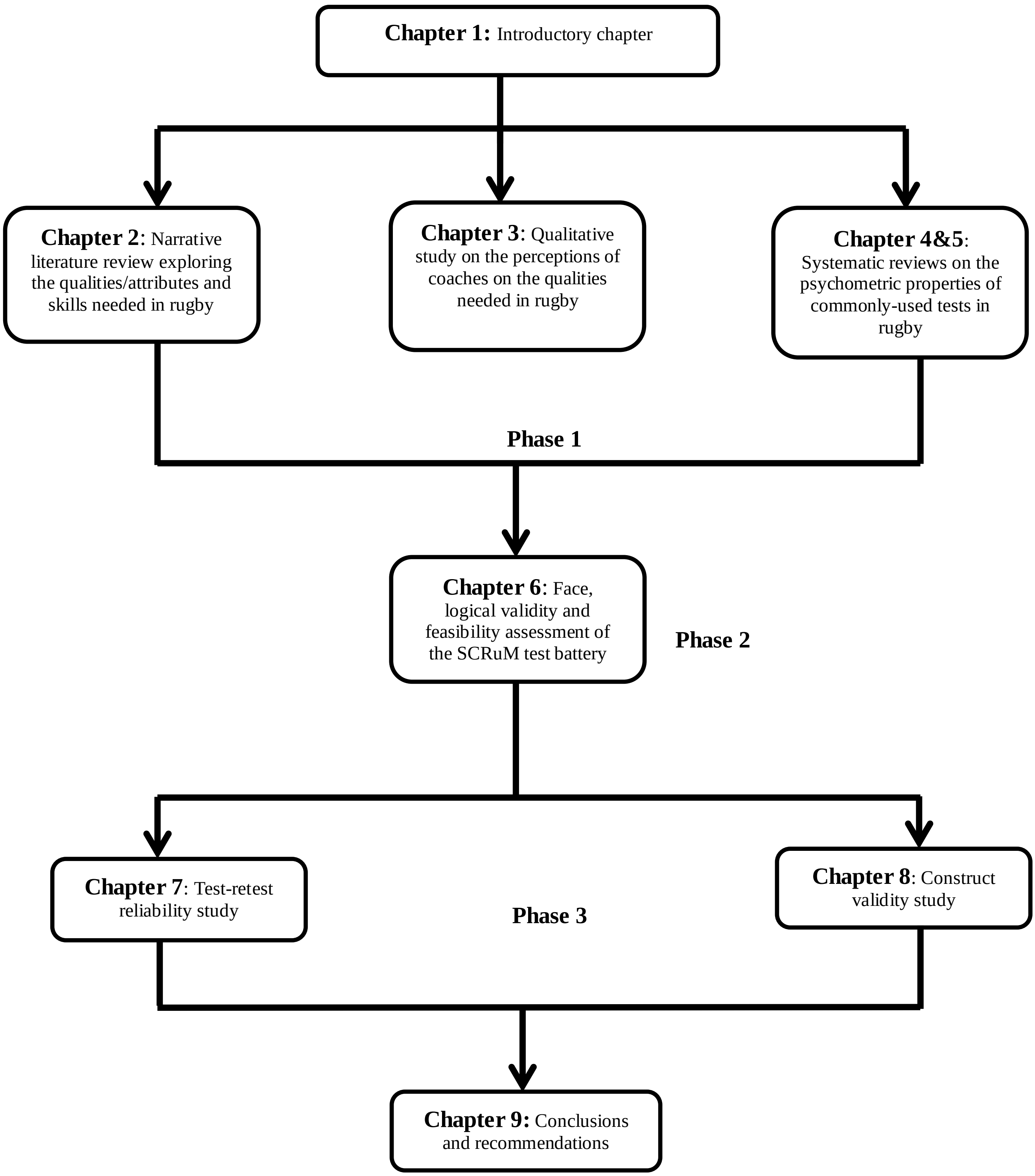


Figure 1-4: General outline of the thesis

Chapter 1: This chapter served as an introductory chapter providing the theoretical and contextual background underpinning the conduction of the study at the present moment in Zimbabwe.

Chapter 2: This chapter served as a literature review aimed at understanding what is known in the literature about the qualities or skills needed by rugby participants.

Chapter 3: This chapter presents a paper exploring coaches' perceptions of qualities defining good male adolescent rugby players and are important for player recruitment in TID programmes. Additionally, the full text[1] of another publication from the qualitative study found on https://www.ncbi.nlm.nih.gov/pubmed/30808412 explored the selection criteria used by coaches for possible inclusion of young players into school rugby teams and reasons for schoolboys' participation in competitive rugby.

Chapter 4: This chapter presented the first systematic review paper investigating the measurement properties of commonly-used tests for assessing physiological characteristics in rugby and related intermittent contact team sports. The systematic review was guided by a protocol[2] found on https://www.ncbi.nlm.nih.gov/pubmed/27460647. Due to the unanticipated large volume of data found during the literature search, the protocol was split into two distinct reviews.

Chapter 5: This chapter presented the second systematic review on rugby-specific game skills guided by the same protocol[2] mentioned above.

Chapter 6: This chapter presented a publication on the face, logical/content validity and practical feasibility of the test items in the SCRuM test battery. In the content of the article, the paper described the factors considered during the selection of variables and corresponding tests for inclusion in the first version of the test battery.

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[1] Chiwaridzo M, Ferguson GD, Smits-Engelsman BCM. High-school adolescents' motivation to rugby participation and selection criteria for inclusion in school rugby teams: coaches' perspective (the SCRuM project).

[2] Chiwaridzo M, Ferguson GD, Smits-Engelsman BCM. A systematic review protocol investigating tests for physical or physiological qualities and game-specific skills commonly used in rugby and related sports and their psychometric properties.

Chapter 7: This chapter presented the reliability study involving male adolescent RU players playing in the SESRL for the U16 and U19 age categories.

Chapter 8: This chapter presented a published paper investigating anthropometric, physiological characteristics and rugby-specific game skills of schoolboy players of different age categories and playing standards. This chapter constituted as the main study aimed at answering the specific primary research questions which are highlighted in section 1.5 of Chapter one.

Chapter 9: This chapter concluded the thesis providing a summary of the major findings and possible recommendations emanating from the study findings.

1.12 Conclusion

This chapter constituted the introductory chapter providing largely the theoretical and contextual background to a study aimed at identifying anthropometric, physiological characteristics and rugby-specific game skills in the SCRuM test battery defining good Zimbabwean male adolescent rugby players. To achieve this, this chapter proposed developing a test battery ultimately composed of reliable, valid and practically feasible test items followed by a comparative analysis of anthropometrical and test performances among a sample of elite, sub-elite rugby players and elite non-rugby players within and between U16 and U19 age categories. Chapter one provided an overview of the dynamics and structure of the game of rugby within Zimbabwe and potential challenges. This chapter further explained the indispensable role that schoolboy rugby plays in the survival of Zimbabwe senior rugby and how fully understanding the anthropometric, physiological characteristics and rugby-specific skills discriminating rugby players of different age categories and playing standards would ensure implementation of specific training programmes sensitive to the playing abilities and characteristics of young rugby players. This chapter also outlined the structure of the thesis to be followed in answering the proposed primary and secondary research questions.

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2 CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This literature review chapter constituted the first part of Phase I. The significance of the chapter to the generality of the thesis was to identify theoretical variables possibly important for rugby for possible inclusion in the first version of the SCRuM test battery. This entailed reviewing relevant literature to determine what is known about the qualities or skills needed by rugby participants, ultimately producing a list of variables theoretically reflecting the key requirements of the sport. Therefore, this chapter specifically reviewed the literature to describe:

i. The sport of rugby (general description of the play of rugby and positional roles and the implications of that information on understanding the qualities or skills possibly needed by young schoolboy rugby participants).
ii. The rugby match demands (general review of physical and physiological demands of competitive rugby with particular emphasis on schoolboy rugby).
iii. The qualities or skills discriminating players of intermittent contact team sports such as RU, rugby league (RL) and Australian Rules Football (AFL) by competitive level and/or age category.

2.2 Description of the sport of rugby

2.2.1 The play of rugby

Rugby has historical roots dating back to the 19th century [1]. Whilst playing football, legend has it that a 16-year old schoolboy named William Webb Ellis “picked up the ball and ran with it” to score [2]. This is widely believed to have led to the development of the concept of rugby and adoption of the current style of play characterised by catching or “picking” and “running with the ball” towards the opponents’ goal line [2, 3]. However, rugby maintained its amateur standing until 1995 when players acquired professional status [4]. Today, rugby is a popular international sport played by all ages and sexes at different competitive levels [5-8]. Reportedly, it is now second to soccer in terms of the number of countries in which the sport is played [9].

Rugby union is played on a rectangular field, using an oval-shaped ball, by two opposing teams of 15 or 7 players each [1, 10-20]. The total duration of the rugby matches varies according to the playing level with U13, U16, U18, and seniors playing for two periods of 20 minutes, 30 minutes, 35 minutes and 40 minutes, respectively [18, 21, 22]. The first and second halves are separated by a half-time break of 10-15 minutes [15, 18, 22]. Additional stops occur in cases of injuries, substitution, penalty kicks, conversion attempts and when the ball runs off-field [20, 23].

Rugby matches typically start with a kick-off with the opponent team players in a horizontal defensive line [24]. Thereafter, the game of rugby is characterised by four distinct phases based on the main activities occurring: open play, tackling, rucking and mauling, and set pieces (scrummaging and lineout) [25, 26]. The term ‘open play’ refers to periods in match play when the ball is being passed or kicked between teammates and both teams are contesting for the ball [27]. Tackles are defensive body-contact actions of bringing an offensive ball carrier to the ground halting forward progression [7, 21, 28]. In modern-day rugby, most injuries sustained in rugby are reported to occur during tackle situations because of frequent exposure and high impact forces [25, 29]. A ruck often follows a tackle and occurs when the ball is on the ground and players from opposing teams fight for the possession [26]. Mauls occur if at least one opponent holds the ball carrier and one or more teammates bind on the ball carrier [21]. Scrums usually occur after infringements and the eight forward players from the two teams form a tunnel for ball placement and contestation [21, 26, 30]. Lineouts restart match play when the ball has gone off-field and involves player lifting in order to catch the ball [26].

The main objective of rugby competitions is to win the match by advancing into opponents half, breaking defense lines and scoring [1, 18, 24]. To score most points, ball possession is considered crucial [31]. All rugby players use physical qualities, technical abilities and skills during acts of contact, running, scrummaging, lineouts and open play to maintain or retain ball possession [29, 31]. Additionally, rugby players use technical manoeuvres of running, passing sideways, backwards or kicking the ball into the opposition's territory to break defensive lines and score points [13, 21]. A "try" is scored when the ball is carried and grounded over the goal line and five points are awarded. Thereafter, the team that scores kicks the ball in a "conversion kick" aimed between the goalposts for two more points. The game then restarts at the half-way line with another kick-off [13].

2.2.2 Generic positional roles

The major playing positions within a rugby team are collated into two generic groups of "forwards" and "backs" [1, 18, 32-36]. Each team contributes eight (8) forward players and seven (7) backline players [32]. This classification is widely used and illustrates the offensive and defensive nature of rugby [7, 18, 37-40]. Despite this classification, all rugby players have the responsibility of attacking and defending for the team, competing and maintaining ball possession alongside performing individualistic roles [20]. This implies that there are general qualities or skills all rugby players should possess as minimal requirements to enable effective participation in rugby situations and special attributes allowing the performance of position-specific tasks. In contemporary rugby, there is a shift towards blending or crossing-over of roles to achieve a balanced team able to attack and defend as a strong unit [41]. This requires all rugby players to have strength, speed, agility, endurance and proficiency in game-related skills [36, 42, 43].

Specifically, the forward players are known as the offensive stalwart of the team always contending for ball possession with the opposition team [32, 37, 44]. In terms of specific positions, forward players are named as: props (n=2), hookers (n=1), locks (n=2), flankers (n=2) and eighth man (n=1) [23]. The props, hookers and locks bring in the body mass, muscular strength and power to the attacking prowess of forwards [37]. The flankers and number eight players offer versatility, agility, manoeuvrability, evasion skills and speed to the forward attack. To retain ball possession, all forwards engage in high-intensity static actions (mauls, rucks and scrums) and heavy impact tackles [7, 16, 20, 23, 37, 44]. This role requires all forward players to have upper-and-lower body muscular strength and power and efficient anaerobic capacity for effective performance in power-based aggressive tasks and re-engagement in physical tasks following exertion [33]. In a study evaluating the positional demands of international rugby players, Quarrie et al [44] found that forwards are involved in scrums, mauls and rucks for about three and half minutes per match as compared to less than a minute for the backs. Moreover, forwards were shown to be involved in more than 30 rucks per match whilst backs are involved in half the number. Since both forwards and backs are involved in the physical contestations except scrums, Quarrie et al [44] findings suggest that rugby is a physical sport and requires all players to be physically strong to counter the high degree of contact and impact. Figure 2-1 below shows the rugby positions.

Acknowledgment of source (https://www.ruck.co.uk/rugby-positions-roles-beginners/)

Figure 2-1: Rugby positions

The main function of backline players is to gain possession of the ball through defensive actions such as tackling and use of high-intensity speed runs to gain territory, attack and assist forwards in scoring [20, 32, 37, 44]. This requires speed, agility, reactive agility, adept ball-handling skills for the effective execution of the back roles [41]. There is also an additional requirement for upper and lower-body muscular strength and power for sprinting, tackling, rucking and mauling. For example, wingers use their explosive speed, agility and evasive skills to finish off attacking moves in try-scoring and for covering back in defence [45]. They also need strength to counter defensive tackles during sprinting. The other backline position players include scrum-halves, fly-halves, inside and outside centres, full-back [18, 23] (Figure 2-1). The scrum and fly-halves link the forward and back players and require speed, endurance, ball passing and kicking skills as they need to accelerate away from the approaching defenders and as they control possession of the ball obtained by the forwards [23].

Table 2-1 below summarises the key findings from the description of the sport of rugby highlighting possible implications on the needed qualities or skills for rugby. Collectively, the physical qualities or skills needed in rugby seem to range from endurance, running ability, tackling, passing, kicking, rucking, mauling, scrummaging, offensive skills, defensive skills and ball possession skills. Potentially, all these variables could be included in test battery designed for profiling rugby players.

Table 2-1: Key findings from studies on rugby description

Key findings from the description of rugby	References	Individual qualities or skills needed
The total duration of the rugby matches varies according to the playing level with U13, U16, U18, and seniors playing for two periods of 20 minutes, 30 minutes, 35 minutes and 40 minutes, respectively.	[18, 21, 22]	i. Endurance/Aerobic fitness
Rugby matches typically start with a kick-off with the opponent team players in a horizontal defensive line.	[24]	i. Kicking ability ii. Defensive ability skills
The game of rugby is characterised by four distinct phases: open play, tackling, rucking and mauling, and set pieces (scrummaging and lineout).	[25, 26]	i. Passing ii. Catching iii. Kicking iv. Running ability v. Repeated sprinting ability vi. Tackling ability vii. Rucking ability viii. Mauling ability ix. Scrummaging ability x. Lifting ability xi. Throwing ability xii. Muscular strength and power xiii. Aerobic fitness xiv. Anaerobic capacity
The main objective of rugby competitions is to win the match by advancing into the opponents half, breaking defence lines and scoring.	[1, 18, 24]	i. Offensive ability skills ii. Defensive ability skills iii. Scoring abilities
All rugby players use their physical, technical abilities and skills during acts of contact, running, scrummaging, lineouts and open play to maintain or retain ball possession offensively or defensively.	[29, 31]	i. Physical characteristics (strength, body mass, power) ii. Speed iii. Technical abilities iv. Skills v. Ball-handling skills
Rugby players use technical manoeuvres of running, passing sideways, backwards or kicking the ball into the opposition's territory to break the defensive lines and score points.	[13, 21]	i. Running ability ii. Passing ability iii. Kicking ability iv. Offensive ability skills v. Defensive ability skills vi. Scoring abilities

After scoring a try, the team that scores kicks the ball in a “conversion kick” aimed between the goalposts for two more points. The game then restarts at the half-way line with another kick-off.	[13]	i. Kicking ability ii. Visual abilities
All rugby players have the responsibility of attacking and defending for the team, competing and maintaining ball possession alongside performing individualistic roles.	[20]	i. Attacking ability ii. Defensive ability iii. Competitiveness iv. Ball possession skills
The forward players are known as the offensive stalwart of the team always contending for ball possession with the opposition team.	[32, 37, 44]	i. Competitiveness ii. Ball possession skills iii. Offensive ability skills iv. Defensive ability skills
To retain ball possession, all forwards engage in high-intensity static actions (mauls, rucks and scrums) and heavy impact tackles.	[7, 16, 20, 23, 37, 44]	i. Rucking ability ii. Mauling ability iii. Scrummaging ability iv. Tackling ability v. Ability to engage in high-intensity static actions vi. Repeated ability to engage in high-intensity static actions vii. Anaerobic capacity viii. Aerobic fitness
The main function of backline players is to gain possession of the ball through defensive actions such as tackling and use high-intensity speed runs to gain territory, attack offensively and score points.	[20, 32, 37, 44]	i. Defensive ability skills ii. Tackling ability iii. High-speed running ability iv. Repeated high-speed running ability v. Offensive ability skills

2.3 Match demands in rugby

Several studies have been conducted targeting players at different levels of competition to understand physical, physiological and kinematic demands of rugby [13, 23, 46, 47]. Importantly, rugby demands provide a framework for understanding qualities and skills important in rugby through evaluation of the movement patterns common in rugby and how rugby players physiologically respond to match situations [48]. One of the earlier comprehensive reviews highlighted the anthropometric and physiological characteristics generally required for rugby performances by elite senior players [47]. Another review by Duthie et al [23] was relatively broader in scope and covered physical requirements of rugby and positional differences in the physical capacities between forwards and backs. However, one limitation of the review was the lack of depth in sections describing match demands, especially for adolescent rugby players. This is probably because of limited studies conducted before professionalisation describing the match demands of rugby. The review by Duthie et al [23] was published more than 15 years ago, several articles and technologies such as Global Positioning Systems (GPS), accelerometers, gyroscopes, and semi-automated camera systems detailing and quantifying match demands of rugby players have emerged.

Ziv and Lidor [13] published a qualitative review of studies examining on-field match demands of RU players. The small number of studies (n=16) included in the qualitative review, 12 years after the review of Duthie et al [23], warrants continued collection of empirical movement pattern data or suggest that many studies were not included in the review. Hogarth et al [46] also published a review article evaluating the physical demands of different professional rugby football codes from RL, RU and rugby sevens from studies published from 2008 to 2015. Their review was encompassing in terms of sports included and made direct comparisons between sports. However, the review only extracted data from seven (7) RU studies. Also, the authors only summarised findings on total distances, relative distances and the percentage of high-intensity running from the included studies. Further assessments of the demands of rugby during training and match play, for both senior and junior players, are warranted to guide test battery design.

2.4 Search strategy

A literature search conducted by the author in *Academic Search Premier, Africa Wide Information, Scopus, Google Scholar, PubMed*, and *Medline* for studies published between January 1, 1995 and December 31, 2016, using key search terms such as *"rugby"*, *"physical demands"*, *"time-motion analysis"*, *"TMA"*, *"global positioning system"*, *"GPS"*, *"physiological demands"*, *"match demands"* and *"training demands"*, revealed 25 studies quantifying match demands in RU players. The analysis of the 25 studies was conducted to understand the physical demands of rugby for all players, movement patterns commonly observed in rugby and make comparisons between forward and back players to draw conclusions on the possible qualities and skills that could be needed in the sport of rugby. Moreover, the review compared results on match demands between adolescent and senior rugby players.

2.5 Key findings

This review identified nine (9) more articles than the previous review of Ziv and Lidor [13] had included and had eighteen (18) articles more than the review published by Hogarth et al [46]. Appendix A summarises key findings from studies investigating match demands in rugby.

2.5.1 Study characteristics

Of the 25 studies, nine (9) used video-based TMA recordings and automated or semi-automated multiple camera systems, fifteen (15) used GPS technology coupled with digital compasses, accelerometers and gyroscope technologies and one (1) study combined GPS and video-based TMA in concurrent analysis of training and match demands for rugby players. The majority of the studies (n=17) involved elite male senior rugby players playing club or international rugby from countries such as Australia, England, France, Ireland, Italy, NZ, Scotland, Spain, SA, and Wales. One study compared the movement demands of elite U20 and senior international male rugby players. Only seven (7) studies specifically investigated kinematic data from TMA or GPS studies for male junior players from Australia, England, SA, Spain and Wales [38, 48, 49, 50, 51, 52, 53]. The majority of these studies included junior adolescent male players playing competitive rugby for the U16 to U19 age-categories with age ranges from 15.4±0.4 to 18.6±0.5 years [38, 48, 49, 50, 51, 54]. The sample sizes for the studies included in the review ranged from 2 to 763 junior and senior rugby players.

2.5.2 Total match distance

Several studies provided information on the total distances covered by rugby players in competitive and training matches. The inter-study variations were due to the differences in method of analysis (either GPS or TMA), level of competition (club rugby vs. international rugby), playing style (southern vs. northern hemisphere), standards of play (professional vs. semi-professional), players assessed, sample size, ball-in-play time, opponents tactics, refereeing style, weather conditions, and period in the rugby season the games were assessed [40, 52, 55]. For young rugby players, the distance covered was relatively less than that reported for senior players, ranging between 3.79km to 5.75km. Although not appropriate to provide direct comparisons of total distance covered between senior and junior players because of the differences in playing time, Roberts et al [40] attributed the differences in total distance to different playing style between junior and senior players and the fact that young players are physically less developed impacting on the distance travelled.

Another key finding emerged from a preponderant of studies was that backline players covered significantly greater distances than forwards in match play. However, one study showed that young forward players especially the front-row forwards (FRF) covered greater total distances than backs [50]. Another study showed no significant difference in the total distance covered during match play between the young backline and forward rugby players [48]. Furthermore, this review also showed that rugby players generally cover greater total distances during competitive match play than during training especially for young rugby players [51, 56].

2.5.3 Movement characteristics observed in rugby

Studies quantifying match demands have used varied terminology to describe the movement patterns observed during match play in rugby. Appendix A, under the column of “movement/variable assessed”, shows terms used to describe locomotor patterns and states of exertion observed in rugby matches and training. Rugby movements are often coded into two main categories: “low-intensity activities (LIA)” and “high-intensity activities (HIA)”. This review showed that all rugby players irrespective of the level of competition and age category perform multiple LIA and HIA. This happens continuously for the duration of the match without a significant difference between the two halves [57]. However, the majority of match playtime is spent by rugby players in LIA. Table 2-2 below provides the operational definitions of common movement patterns described under LIA and HIA in some of the pre-selected studies included in the review.

Table 2-2: Terms used in movement classification from selected studies

Movement pattern	Austin et al [28]	Deutsch et al [58]	Duthie et al [57]	Eaton and George [59]
Standing still	Standing or lying on the ground without being involved in pushing or any other game activities.	Standing or lying on the ground without being involved in pushing or any other game activities. This includes small movements when such movements are not purposeful (stumbling back and forth, turning sideways).	No locomotor movement.	None.
Walking	Walking forwards or backwards slowly with purpose. One foot in contact with the ground at all times.	Walking forwards or backwards slowly with purpose. One foot is in contact with the ground at all times (walking to a scrum following a break down).	Locomotor movement without a flight phase	None.
Jogging	Jogging forwards or backwards slowly to change field position, involves a flight phase, with minimal arm swing, but with no particular haste.	Running forwards slowly to change field position but with no particular haste or arm drive (jogging downfield to a line out).	Locomotion with a flight phase but minimal arm swing.	None.
Striding	Running with manifest purpose and effort, accelerating with long strides, yet not at maximal effort (3/4 pace, running into a back-line to receive the ball).	None.	Similar to jogging with a more active arm swing.	None.
Cruising	None	Running with manifest purpose and effort, accelerating with long strides, yet not at maximal effort.	None.	None.
Sprinting	Running with maximal effort. Discernible from striding by maximal arm and stride movements.	Running with maximal effort and was discernible from cruising by the arm and head movements.	Maximum locomotor effort.	None.
Lateral movement	Shuffling sideways (transverse) to change field position. Usually a defensive or repositioning movement.	None.	None.	None.
Utility	None.	Shuffling sideways or backwards to change field position. Usually a defensive or repositioning movement. This does not include aimlessly walking slowly or backwards.	None.	None.
Jumping	None.	Jumping in a line out or to catch a ball in play.	None.	None.

Rucking/ mauling		Attached to an active ruck or maul. Once the ball exits the ruck or maul or the referee calls the end of the play, the player is no longer considered to be engaged in rucking/mauling, and is deemed to be standing still.	None.	Rucks and mauls started when a player entered the event and cessation was when either the ball was picked up (in the case of the ruck), the ball came out (loose ball or taken by the player), or when the play was stopped for an infringement.
Scrum	A player is attached to an active scrum, ruck or maul. Once the ball exit the scrum, ruck or maul, or the referee calls the end of the play, the player is no longer considered to be engaged in a scrum, ruck or maul.	Attached to an active scrum and as above, once the ball exit or the play is stopped, the scrum is no longer active.	None.	Scrums were times from the point at which the two packs engaged to break-up, regardless of whether the ball was put in or not
Static holds	The involvement of lifting a player in a lineout movement.	None.	None.	None.
Tackling	A tackle occurs when the ball carrier is held by one or more opponents and is brought to ground.	None.	None.	A tackle was timed from the point of the first contact.
Lineout	None.	None.	None.	Lineout started from the moment the ball left the throwers hand and ended once the jumper had landed.
Kicking	Any kick in play including; kick-off, kick to touch, chip-kick, punt, and a field goal.	None.	None.	None.

Deutsch et al [49] classified observed movement patterns of young rugby players into six gait patterns (standing still, walking, jogging, cruising, sprinting and utility) and had two states of "static exertion" (rucking/mauling and scrummaging). However, they further classified the movement patterns into two distinct categories: work periods representing HIA (cruising, sprinting, rucking/mauling and scrummaging) and rest periods representing LIA (standing still, walking, jogging and utility movements). Similarly, Duthie et al [57] classified the movements into five locomotor patterns of "standing", "walking", "jogging", "striding" and "sprinting" and three states of "static exertion" (scrums, rucks and mauls). The authors further included movement patterns of "jumping", "lifting" and "tackling". Work periods suggesting HIA were defined as "striding", "sprinting" and the three states of static exertion, whilst "standing", "walking" and "jogging" were LIA or rest periods.

Eaton and George [59] classified movement patterns into LIA (jogging, walking and standing), HIA (sprinting, high speed runs, running) and non-running HIA (scrums, rucks/mauls, tackling and lineouts). Deutsch et al [58] used the same movement classification system with six speeds of locomotion as in Deutsch et al [49]. However, in place of static exertions, the former authors had "non-running intensive exertion" activities (rucking/mauling, tackling, and scrummaging) and "discrete" activities (kicking, jumping and passing). They further categorised "cruising", "sprinting", "rucking/mauling", "scrummaging" and "tackling" as HI work periods and "standing", "walking", "jogging", and "utility movements" as rest activities. Austin et al [28] refined the categorisation of the movement patterns for senior professional players into "locomotion" (standing, forward walking, backward walking, forward jogging, backward jogging, forward striding, forward sprinting, and lateral movement), "non-running intense activities" (tackling, static holds or lifts, scrummage) and "discrete activities" (kicking). Forward striding and sprinting, tackling, static holds and scrums were characterised as HI work periods.

2.5.3.1 Low-intensity movement activities

Although there is minimal involvement of physical exertion, activities such as standing, walking, jogging and utility movements have been described as LIA or "rest" periods. Rugby players spent a greater percentage of time in LIA during match play or training. Among 24 young elite rugby players, Deutsch et al [49] showed that 85% of match play was spent in LIA such as standing, walking, jogging and utility movements. Eaton and George [59] found that the relative time spent in LIA ranged from 87.9% to 93.5% for the various individual playing positions among 35 elite senior rugby players. Similarly, Duthie et al [57] found that Super 12 forward rugby players in Australia playing in the 2001 and 2002 season spent 86% of the time in LIA of standing, walking and jogging and backs spent 94% in total. In another TMA study, Austin et al [28] showed that Super 14 rugby players had relative times (%) for LIA of 79±15 for FRF, 79±15 for back row forwards (BRF), 84±15 for inside backs (IBs) and 85±3 for the outside backs (OBs). Coughlan et al [7] used GPS technology and showed that rugby players spent almost 75% of the total match distance in LIA. Roberts et al [40] showed that the mean (±s) total time spent in LIA per single match by senior elite rugby players was 70:51±1:39 for forward players and 76:56±1.01 for the backs, highlighting the preponderance of LIA in rugby matches for both forward and back players. Tee et al [60] investigating match demands of professional senior SA rugby players found that the majority of the playing time (79%-84%) was spent walking by all rugby players.

Standing/standing-still/inactive/stationary

Irrespective of rugby positions, Deutsch et al [49] found that young (n=24, mean age±SD=18.4±0.5 years) Australian rugby players participating in the first division of the Brisbane Metropolitan U19 rugby competition spent a greater percentage of game time "standing-still" compared to walking, jogging or lateral/utility movements. Hartwig et al [51] also showed similar results of adolescent rugby players spending on average more time stationary in training matches (45%) as well as in competitive games (38%). These findings were also expressed in another TMA study involving 29 senior professional rugby players from Otago Highlanders club in NZ competing in the Super 12 international matches conducted by Deutsch et al [58]. Duthie et al [57] quantified the movements of 47 Super 12 rugby players in competition during the 2001 and 2002 season in Australia using TMA and also found that senior rugby players relatively spent a greater percentage of total time in standing activities than in walking or jogging. However, in contrast to all these findings, Eaton and George [59] found that standing was the third most frequent LIA senior rugby players frequently engaged in, after the activities of walking and jogging. In a GPS study with a relatively small sample size of two rugby players (n=1 forward, n=1 back) with the mean age of 30 years conducted by Coughlan et al [7], “standing or non-purposeful movements” were the second most frequent LIA following walking. Overall, these findings seem to suggest variability in the relative time spent in LIA for senior rugby players as compared to junior players who invariably spent most time inactive or standing. These contrasting findings highlight the difference in the sample population and the level of competition between junior and senior rugby. However, senior rugby may be fast-paced with reduced mean duration in standing as compared to junior rugby. Eaton and George [59] found that the mean duration for standing in a single match of rugby for the senior players ranged from 3.56±1.38seconds to 4.54±0.57seconds depending on rugby positions. These figures were significantly lower than the average durations reported for junior rugby players by Deutsche et al [49].

Walking

Deutsch et al [49] found that walking was the third most common movement activity characterising LIA of young rugby players playing first division rugby in Australia. The mean relative percentage time spent walking by junior players ranged from 14.7±1.8 to 27.5±2.7 with clear differences between backs and forwards. Backs spent a significantly greater percentage of time walking compared to forward players (27% *vs*. 15%, $p<0.05$). Duthie et al [57] also showed similar overall results among professional Super 12 rugby players. Backs significantly spent more time (%) walking compared to forward players (38±10 vs. 27±7). However, comparing junior and senior rugby players, Duthie et al [57] study had higher values on the relative time spent walking as compared to the study by Deutsch et al [49] which sampled junior rugby players. These findings possibly highlight differences in match demands between senior and junior rugby.

Eaton and George [59] showed that walking was the most frequently engaged LIA by rugby players from one professional rugby club assessed over six games in the English Premiership. However, in contrast to the findings of Duthie et al [57], the former authors showed that senior rugby players spent a greater percentage of the match walking than standing or jogging depending on rugby positions. The relative time spent walking ranged from 45.72±2.80 for the hookers to 61.92±3.70 for the OBs. The relative time (%) spent walking by the OBs significantly differed with the values reported for all the forward positions (props, hookers, lock and loose forwards). These findings of backs relatively spending more time walking are consistent with the findings from other studies [18, 40, 50, 51, 58, 60]. Hartwig et al [51] demonstrated that the relative time (%) spent walking by the adolescent back players was 48±7.6 compared to 35.5±4.2 for the forwards. The authors also showed that adolescent back rugby players walked more during training sessions as compared to the forwards (48.1±7.7 *vs*. 45.0±8.8). Among 19 professional senior SA rugby players with the mean age of 26±2 years playing in the 2013 rugby season gathered from one rugby team, the percentage time spent walking ranged from 79±7 to 84±5 depending on rugby positions [60]. But, on average, backs were shown to have spent a greater proportion of time walking than forwards (80% *vs* 83%).

Jogging

Findings on rugby positions predominantly spending a greater percentage time in "jogging" activities vary depending on the study population investigated. Other studies showed no significant differences between the two generic groups whilst others reported forwards spending more time than backs. Deutsch et al [49] showed that jogging was the second most frequent LIA young rugby players engage in game matches. Comparing between forwards and backs, the authors, however, showed that forward players covered significant distances in "jogging" than backs ($p<0.05$). Forwards were shown to have covered on average 2 990m as compared to 2 470m for the backs. Nonetheless, no significant differences were reported by Deutsch et al [49] in the mean relative time (%) spent in jogging between forwards and backs, as FRF jogged for 20.8±0.9, BRF for 20.3±0.9, OB for 18.2±1.7 and IB for 19.2±1.6.

Albeit in senior rugby players playing in the English Premiership, Roberts et al [40] showed comparable findings to Deutsch et al [49] of rugby players covering greater total distance in jogging activities than in other movement categories. However, the findings of Deutsch et al [49] on the total distance jogged were slightly more than the 2024±400m reported for senior rugby forwards and 2010±340m reported for senior rugby backs by Roberts et al [40]. These findings reflect differences in the level of competition between senior and junior rugby players and different levels of playing intensities. Roberts et al [40] findings were consistent with the GPS findings of Cunniffe et al [61] on the distance jogged. The latter authors reported total mean jogging distances to be 1 956m for the one back player and 1 856m for the one forward player utilised in the study. Similarly to Deutsch et al [49], a motion analysis study of adolescent rugby players showed no significant difference in the percentage time spent jogging between forward (14.5±2.7) and backs (13.6±2.5) during competitive matches [52]. In senior rugby players, Duthie et al [57] showed no significant difference in the mean frequency of jogs between forwards (186±31) and backs (177±35). But, in terms of the percentage of total time spent in jogging per game, the forwards (20±4) were shown to have spent significantly ($p<0.05$) more time in joggings than backs (16±4). Similarly, Deutsch et al [58] also showed that forwards spent relatively more time jogging than backs, with the FRF spending more time than any other positional group. Cunniffe et al [61] also found that forward players (24.3%) spend significantly more time jogging than backs (13%). These findings were also similar to the results of Venter et al [50]. The latter authors found that FRF (26.11±3.77) spent significantly more time jogging than OB (15.63±2.30).

Utility/lateral movements

Few studies identified "utility" movements as shuffling movements either sideways or backwards observed when players change field position [49, 58]. Austin et al [28] referred to them as "lateral" movements. Deutsch et al [49] showed that utility movements had reduced mean frequency of occurrence in rugby matches of junior players compared to other LIA such as standing, walking and jogging. Comparing between forwards and backs, the young back players significantly spent a greater amount of percentage time performing utility movements than forwards (OB=8.5±1.4; IB=7.7±0.8 *vs.* FRF=1.7±0.6; BRF=2.8±0.6). These findings were consistent with findings of another TMA study albeit conducted among senior professional rugby players by Deutsch et al [58]. The latter authors found a significant difference in the relative time (%) spent in utility movements between backs (3.6±1.1) and forwards (1.4±0.9). The relative times were comparatively lower in senior rugby players than in junior rugby players as evidenced by the results of the two studies. As reported by Deutsch et al [49], the IBs had the most occurrence of utility movements (67.1±19.5) compared to any other positional groups. In support of the lower relative times (%) of utility movements in senior rugby players playing various forms of Super Rugby, Austin et al [28] showed that the mean relative time for the forwards was 1±0 and for the backs was 2±0.

2.5.3.2 High-intensity (HI) movement activities

Rugby is an intermittent activity sport with LIA interspersed shortly with episodes of HIA such as cruising, striding, HI running, sprinting, maximum sprinting, static exertions (rucking, mauling, scrummaging), and tackling. All studies included in this review showed that rugby players, irrespective of the level of competition and position, spent relatively less time in HIA compared to LIA. Deutsch et al [49] reported mean relative time (%) for static HIA to be approximately 15% for young elite rugby players in Australia. Austin et al [28] reported the mean relative time (%) of 18% for HIA per single match for senior rugby players in Australia.

Cruising and/or striding

According to Austin et al [28] and Deutsch et al [58], the operational definitions for "cruising" and "striding" were similar, referring to purposeful but sub-maximal running efforts. However, other authors separated them into two distinct categories. Cunniffe et al [61], Suarez-Arrones et al [62] and Portillo et al [48] defined "cruising" and "striding" similarly. Jones et al [55] analysed distances covered by 33 professional senior rugby players at different velocity zones with "cruising" being assessed at 2.7-3.8m.s^{-1} and "striding" at 3.8-5.0m.s^{-1}. Other studies only assessed the movement characteristic of "striding" however with varied operational definitions [18, 50, 51, 55, 56, 57].

Deutsch et al [49] found that backs significantly covered a greater mean distance in "cruising" than forwards (558 *vs*. 366m, $p<0.05$). As a result, the relative time (%) spent in cruising was significantly higher for backs (IB=2.6±0.5; OB=2.8±0.3) compared to the forwards (FRF=1.8±0.5; BRF=1.9±0.2). These results were similar to the findings reported for senior rugby players by Deutsch et al [58] which also revealed higher values for backs (2.5±1.1 *vs*. 1.2±1.0, $p<0.0125$). These results were because of increased mean frequency of cruising for the backs compared to the forwards. However, a similar study utilising TMA conducted by Austin et al [28] involving senior professional rugby players showed no statistically significant difference in the relative time (%) striding (defined operationally as cruising) between the back and forwards (7.5% *vs.* 6%). The relative time for the Super 14 rugby players in Austin et al [28] study who played in the 2008 and 2009 season study was, however, comparatively greater than reported for Deutsch et al [58] Super 12 rugby players during the 1996-1997 season. Similarly, Duthie et al [57] found no statistically significant difference between backs and forwards for the relative time spent in striding activities as observed by Austin et al [28]. The former authors conducted time-motion analyses of 47 Super 12 rugby players playing during the 2001 and 2002 season and found that backs spent 2.1±0.8 percentage time compared to 1.7±0.9 for the forwards. In one of the pioneer studies to evaluate the physiological demands of elite rugby players using GPS tracking software, Cunniffe et al [61] showed similar results as reported by Austin et al [28] of no significant difference between backs and forwards in the percentage time spent in speed zones for cruising (3.1 *vs.* 3.4) and striding (3.7 *vs.* 3.8). The former study had the limitation of having utilised only two (one forward and one back) senior rugby players purposively-selected for the study. Nonetheless, their findings were shared by Hartwig et al [51] who also found similar mean values for "striding" as reported by Cunniffe et al [61] of 3.6±3.5 for the adolescent rugby forward players and 3.1±1.8 for backs.

Venter et al [50] characterising movement patterns of U19 semi-professional male rugby players, defined "striding" as speed zones between 51%-80% of the maximum speed (Vmax). This definition was similarly used by Duthie et al [57] assessing the sprint patterns in rugby players during competition and by Cahill et al [18] investigating the movement characteristics of English premiership rugby players. Venter et al [50] found that the mean percentage time spent in the speed zone for striding ranged from 2.84±0.45 for the OBs to 9.58±4.59 for the FRF. Generally, the forwards showed relatively higher mean striding values than back players. Cahill et al [18] compared the median relative distance (m) travelled striding between forwards and backs and found no significant difference between the two [median (IQR): forwards= 860 (440) *vs.* backs=822 (338)]. Similarly, Tee et al [60] found no significant difference between forwards and backs in the relative distance covered during striding in a study assessing the movement and impact characteristics of SA professional rugby players. Also, assessing the relative time (%) spent in striding (defined as speed zones of 4-6ms^{-1}), Tee et al [60] found no significant difference between forwards and back players.

Operational definitions for running efforts

Running efforts are common in junior and senior rugby and occur on a continuum from low-intensity running efforts described as jogging, cruising, and striding to medium effort running called medium-intensity (MI) runs to maximum effort running described variably as high-intensity running, sprinting, maximum sprints or very-high intensity runs [7, 18, 38, 40, 45, 48, 49, 50, 55, 57, 59, 61, 62, 63]. Eaton and George [59] categorised running activities into three distinct categories: runs (>4.0ms^{-1}), high-speed runs (>5.5ms^{-1}) and sprinting (>7ms^{-1}). Tee et al [60] and Tee et al [56] had sprinting activities assessed at >6ms^{-1}. Jones et al [55] had HI running between 5.0-5.5ms^{-1} and sprinting assessed at > 5.6ms^{-1}. Roberts et al [40] had MI running (3.6-5.0ms^{-1}), HI running (5.0-6.7ms^{-1}) and maximal speed running (>6.7ms^{-1}). This classification was also adopted by Coughlan et al [7]. With a slight variation from classification used by Roberts et al [40] and Coughlan et al [7], Reid et al [45] classified LI running as 1.8-3.6ms^{-1}, MI running as 3.7-5.0ms^{-1}, HI running as 5.1-6.7ms^{-1} and maximum speed running as greater than or equal to 6.8ms^{-1}. Read et al [38] had HI running assessed at greater than 3.33ms^{-1} speed zones among adolescent rugby players. Cunniffe et al [61] had HI running defined at 18-20km/hr [5-5.6ms^{-1}] speed zone and sprinting defined at >20km/hr [>5.6ms^{-1}]. Suarez-Arrones et al [62] had a similar classification for HI running and sprinting as defined by Cunniffe et al [61]. Portillo et al [48] also used the same speed zones used by Cunniffe et al [61] for HI running and what they termed “very-HI running”. Hartwig et al [51] assessed sprinting activities at 21+ km/hr [5.8ms^{-1}] speed zone. Venter et al [50] and Cahill et al [18] defined sprinting in terms of the maximum speed (Vmax) as 81-95% Vmax and the maximal sprint was further classified as 96-100% Vmax. From these studies on match demands, running efforts for senior and junior rugby players seem to extend from LI runs (runs) through MI running efforts, HI running efforts to sprinting or maximum speed running or very HI running.

Medium-intensity running

Roberts et al [40] assessed 29 senior professional rugby players and observed no significant difference between forwards and backs in the mean total distance covered in MI runs (812±214m *vs.* 815±215m). Moreover, there was no significant difference in the mean total time (min: s) spent in running at MI speed range per rugby match between forwards and back players (3:15±0.52 *vs.* 3.15±0.52). Coughlan et al [7] in a study involving two professional senior rugby players found relatively higher values for the time spent at MI speed zone compared to the figures reported in Roberts et al [40] study. A forward player in the former study spent on average 5.04 minutes compared to 4.34 minutes spent by the backline player. The frequency of entries into the speed zone for MI running was 224 for forward player compared to 250 for the back player. In terms of the percentage of total distance covered in this speed zone, the forward player covered greater distance of 19.6m compared to 16.2m for the back player. Using eight male rugby players in a case series study design, Reid et al [45] showed the frequency into MI running zones varied between players but ranged from 239 for fly-half to 315 for the locks. The quantity of occurrence of MI runs was significantly greater than HI runs and maximal speed running. This finding was shared by Coughlan et al [7]. The distance covered in MI runs ranged from 954.8m for the loosehead props to 1712.4 for the fly-half. The time (minutes) spent in the speed zone of MI running was also shown to be comparable to what is reported in other studies. Reid et al [45] also found that the players spent 4.22 minutes in the case of loosehead props to 8.10 minutes for the scrum-half.

HI running/High-speed running

Eaton and George [59] found that high-speed runs (> 5.5ms^{-1}) are less frequent than “runs” (>4ms^{-1}) for senior rugby players in England. The mean (±SD) occurrence of high-speed runs ranged from 11±3 for props to 55±13 for scrum-halves. Generally, backs engaged frequently in the high-speed runs than forward players. In terms of the relative time (%) spent in high-speed runs increased significantly from forward players to back players. Roberts et al [40] assessed the relative distance covered by senior rugby players in high-intensity runs. The authors found a significant difference in the mean values for distance by positions with backs covering greater distances than forwards

(448±149m vs. 298±107m). This finding was also supported by Suarez-Arrones et al [62] who also found that senior backs covered significant distances than senior forward rugby players in Spain. Jones et al [55] quantified positional and temporal movement patterns in professional rugby players using GPS and reported similar findings. Also, Roberts et al [40] observed that the distance covered in high-speed runs was significantly less than covered with MI running efforts. With regards to the relative contribution of HI running to the total time (min: s) spent in a single match, the back players were shown to spend 1:19±0.26 which was significantly higher than 0:52±0:19 reported for the forwards. Cunniffe et al [55], evaluating HI running of two senior rugby players (1 forward and 1 back) as movement characteristics performed at 18-20km/hr, found that the two players had an almost equal number of surges or entries into the speed zone for high-intensity runs (backs=43 *vs.* forwards=46). In terms of distance (m) covered by each player, the forward player covered 342m compared to 292m for the back. Consequently, the forward player was shown to have spent a relative greater percentage time in HI running than the back player (1.1 *vs.* 0.9). However, Coughlan et al [7] who used a similar methodological study design and sample size found contrasting results on HI running efforts. The back player had a greater frequency of entries into the speed zone for HI running effort than forward player in the evaluated match (74 *vs.* 56). In terms of the total distance covered, the back player covered significantly more percentage distance than the forward player (7.5 *vs.* 5.6). In the single match assessed, the back player spent 1.32minutes compared to 1.09 minutes in HI running efforts. Also using a small sample size of eight (8) elite rugby players, Reid et al [45] showed that HI runs had less frequency compared to MI runs but had more frequency than maximal speed running in rugby matches. However, the entry frequency into the speed zone for HI running ranged from 48 for the lock to 97 for the inside centre and open-side flanker. In that study, the open-side flanker competed equally with the back players in terms of distance covered and the time spent in the speed zone. For example, the authors found that loosehead prop and lock spent 0.56 and 0.28 minutes respectively in HI running efforts compared to 2.02 minutes for the open-side flanker. For the back players, the time spent ranged from 1.35minutes registered by the scrum-half to 2.02 recorded by the fly-half and wing, respectively. For distance covered in a match of rugby in HI running, the lock and loose head prop covered 134.7m and 260.4m respectively but the open-side flanker covered 595.6m.

The findings for the open-side flanker were comparable to the findings of the back players which ranged from 416.3m to 645.9m. Portillo et al [48] evaluating movement patterns in U19 rugby players showed no significant difference in the distance covered by the nine (9) back players and 13 forward players when using HI runs.

Sprinting

Sprinting is another key movement characteristic defining rugby play for senior and junior players. Variably, studies included in the review reported on the frequency of sprinting activities (n), the relative distance travelled sprinting (m) in relation to the total distance covered during match play, the mean single sprint distance (m), and the relative time (%) spent sprinting during matches and training activities. Of the total distance covered by young rugby players in a TMA study conducted by Deutsch et al [49], sprinting had the least mean total distance covered compared to any other movement characteristic assessed (walking, jogging, cruising, utility) irrespective of position. However, significant inter-positional differences were observed with regards to distances covered during sprinting, back players (IBs=208±52m, OBs=297±37m) covered larger distances compared to the forward players (FRF=94±24m; BRF=94±30m). Comparing the mean single sprint distance, no significant differences were observed for all the positions (FRF=19.8±1.0m; BRF=14.5±3.7m; IB=18.8±2.7m; OB=23.6±1.2m). The maximum distance covered during sprints ranged from 17.0±6.0m for the BRF to 27.1±4.1m for the OBs. Furthermore, in terms of the mean frequency of occurrence, sprinting activities also had the least mean frequency compared to all the other movement patterns assessed especially for the forward players. However, for the back players, sprinting had the second least mean frequency after rucking and mauling. Sprinting was shown to have occurred on average four times (4±1) and six times (6±2) for the FRF and BRF and 12±3 and 15±2 for the IBs and OBs. Consequently, the calculated relative time (%) spent sprinting also showed significant differences with backs (IBs=0.8±0.1; OBs=1.3±0.2) spending more time sprinting than forward players (FRF=0.3±0.1; BRF=0.4±0.1). The mean duration (s) for sprinting for the young players ranged from 2.3±0.6 to 3.3±0.2 with significant differences between the BRF and OBs. All these results showed that young back players sprint more frequently, cover more time and larger distances sprinting compared to the forward players, although the sprinting activities are relatively few for all the positions compared to other activities.

In senior professional rugby players, Duthie et al [57] assessed match demands using TMA and found similar results with the study conducted by Deutsch et al [49]. The former authors showed that sprinting activities were relatively few for back and forward rugby players when compared to other movement activities. However, comparing between backs and forwards, Duthie et al [57] found that the mean frequency (n) for sprinting for the backs was significantly greater than that for the forwards (27±9 *vs.* 11±9). Also, the mean total time (min:s) taken for sprinting in a single game of rugby was generally low, compared to mean total time for standing, walking, jogging, striding and static exertions, ranging from 0:19±0.20 for FRF to 1:24±0:30 for IBs. Overall, the total time for sprinting in a single match was significantly higher for backs than forwards (1:18±0:29 *vs.* 0:27±0:23). Consequently, in terms of the relative time (%) spent sprinting, the authors found that backs spent more time sprinting per game on average compared to the forward players (1.5±0.5 *vs.* 0.5±0.4). The authors did not evaluate sprinting activities in relation to the distances covered. All these results showed that senior professional back players playing Super 12 rugby sprint more frequently and relatively spent a greater amount of time sprinting than forwards.

Eaton and George [59] also investigated the sprinting patterns of senior rugby players playing professional rugby. Consistent with previous studies [49, 57], sprinting activities were minimal for all rugby players compared to other movement activities. These findings may suggest that sprinting is a specialised movement activity utilised by rugby players for specific purposes. In terms of quantity, the mean (±SD) frequency of sprints ranged from 1±1 for the props to 14±5 for the outside backs. Overall, backs frequently engaged in sprinting activities compared to the forward players. This finding was consistent with the findings of Reid et al [45] who reported the frequency of maximum speed running activities from 0 for the lock and scrum-half players to 17 for the fullback player. Consequently, the mean relative time (%) spent sprinting per match was also relatively small for all positions, ranging from 0.02±0.01 for the props to 0.51±0.19 for the OBs. Overall, the authors showed that back players significantly spent more time sprinting during matches than forward players. These findings were also consistent with previous and other investigations involving senior and junior rugby players [7, 28, 49, 50, 51, 57, 60, 61]. The mean single sprint distance (m) increased from 5.7±4.5m for props to 15.2±3.7m for OBs players. It was significantly higher in OBs when compared to any other forward player. Also, the mean duration of the sprints (s) varied by positions with sprints for the back players, especially OBs, lasting longer than for any forward player. Deutsch et al [58] also found similar results as reported by Eaton and George [59]. An overall difference between backs and forwards was observed with regards to the mean frequency of sprinting activities per rugby game. Backs, especially the OBs, engaged in more sprints during match games than forward players. Backs had a higher relative time (%) than forward players in sprinting activities (0.59±0.44 *vs.* 0.20±0.2). In terms of the average time (s) per single sprint, backs sprinted for a significant amount of time compared to the forwards (3.18 *vs.* 2.04).

Although there was no significant difference in the total distance (m) travelled by senior rugby players during sprints, backs covered more distance than forwards (164±189 *vs.* 207±185) in a study conducted by Roberts et al [40]. Also, no significant differences were reported in terms of the mean total time (min: s) taken per single game sprinting between the forward and back players (0:20±0:23 *vs.* 0:27±0:23). The average duration (s) of each sprint showed no significant difference between forwards (1.2±0.3) and backs (1.2±0.3). However, in that study, backs were shown to engage more frequently in sprints compared to forwards (23±19 *vs.* 16±15). Cunniffe et al [61] showed that the one back player in the study covered 524m when compared to the one forward player who covered 313m. This was accounted for by the significant difference in the frequency (n) of sprinting activities recorded between the back and forward player (34 *vs.* 19). Consequently, the back player was found to have spent a greater percentage of time in the speed zone for sprinting compared to the forward player (1.4 *vs.* 0.8). These findings concurred with GPS findings reported by Coughlan et al [7] who similarly conducted a case study with two players (1 forward, 1 back). Suarez-Arrones et al [62] reported similar findings with the majority of the previous studies. The authors found that backs covered larger total distance sprinting than forwards. This was mainly because of the significant mean number of sprints obtained by backs (26.2±10) compared to forwards (11±5). The average maximal distance (m) of a sprint was also larger for the backs compared to the forwards (46.3±12.1 *vs.* 25.9±8.9). Consequently, the mean sprint distance favoured backs (19.5±3.9) compared to the forwards (14.7±2.5). Portillo et al [48] found that the longest "very HI run" (m) was larger for the backs compared to the forwards (36.8±22.2 *vs.* 53.8±13.9), although not statistically significant (p=0.06). The mean shortest "very HI run" was also similar between backs and forwards (8.0±7.8 *vs.* 4.6±2.9, p=0.17). However, on the average distance (m) per "very HI run", the authors found a significant difference between forwards and backs, with the latter players covering greater distances (22.7±5.2 *vs.* 15.5±4.8, p=0.04).

Static exertions (rucking, mauling and scrummaging)

Deutsch et al [49] found that mean frequency of rucking/mauling in a match of rugby was significantly higher for the young forward players compared to the backs (70±7 *vs.* 10.5±2). Consequently, the relative time (%) spent rucking/mauling was higher for the forwards (9.3%) compared to 1.4% for backs. The average time (s) per game spent rucking/mauling was also greater for the forwards compared to the back players (FRF=5.3±0.3; BRF=5.2±0.1; IB=4.0±0.7; 0B=4.6±1.0). Additionally, the authors found that forwards engaged in rucks/mauls twice the frequency than in scrums.

Duthie et al [57] reported higher mean frequency values for static exertions (rucks, mauls and scrums) compared to the figures reported by Deutsch et al [49]. In the former study, the mean occurrence (n) of static exertions per game was significantly greater for the forwards as expected compared to the backs (80±17 *vs.* 21±11). However, in terms of the percentage of total time spent in static exertions, the findings of Duthie et al [57] with the senior professional players were similar to those reported for young rugby players by Deutsch et al [49]. The back players were shown to spend a mean relative time (%) of 10±3 compared to 1.5±0.8 (p<0.05) [57]. In terms of the total time (min: s) taken in static exertions in a single match of rugby, forwards spent on average 9:06±2:48 and backs spent 1:19±0:43 (p<0.05).

Under HI non-running activities, Eaton and George [59] combined and analysed rucking and mauling together separated from scrummaging activities. The mean quantity (n) of rucks and mauls increased linearly from back to forward players (OBs=13±6, IBs=15±9, scrum-halves=15±5, props=38±12, loose forwards=48, locks=49±19, hookers=49±19). Although these results were consistent with the findings of Duthie et al [64] on the mean frequency of rucks/mauls being greater in forwards than backs, the frequency figures by Eaton and George [59] were relatively lower than reported by Duthie et al [57]. Furthermore, the relative time (%) spent in rucks and mauls were also lower than reported in the previous investigations, although the trend hint that forward players spent more time (2.80) in these activities compared to the backs (0.89). The mean (±SD) duration (s) spent rucking ranged from 2.89±0.7 to 4.1±1.6. The only significant differences were observed between props and outside or inside backs. There were no significant differences observed between other forward players and back players. With regards to scrummaging, the forward players were shown to spend a mean combined relative time (%) of 2.99. There were no significant differences observed in mean relative time spent scrummaging by all the forward players. As observed in the study by Deutsch et al [49], the mean frequency of the scrums among senior forward players was relatively lower compared to the mean frequency of occurrence of rucks and mauls. On average, Eaton and George [59] found forward rugby players scrummaging at a frequency of 28 scrums per match as compared to 46 rucks and mauls. In terms of the mean duration (s) scrummaging per rugby match, there were no significant differences among all forward positions. The combined mean duration was 5.85 seconds. This finding was consistent with the findings of Deutsch et al [49] in young forward players playing elite rugby. Deutsch et al [49] observed a combined mean duration of 5.75 seconds.

Similar to Eaton and George [59], rucking/mauling and scrummaging were categorised distinctly under non-running intense exertion by Deutsch et al [58]. The findings of the latter authors were consistent with the previous investigations on rucking/mauling being performed predominantly by the forward players compared to the backs. Deutsch et al [58] found that the combined mean (±s) frequency for the forwards was 66.9±15.8 compared to 9.5±5.7 for the backs ($p<0.05$). These results were also shared by Deutsch et al [49], albeit in young adolescent rugby players. Deutsch et al [58] also reported on the combined average time (s) taken rucking/mauling and compared between forwards and backs. The authors failed to observe any significant differences between groups (4.7±0.8 vs. 4.2±0.8). Also, the relative time (%) engaged in rucking or mauling also differed by positions. The forward players performed more rucking/mauling than either of the groups of backs used in the study. These findings were consistent with other studies [49, 57, 59]. With regards to scrummaging, the combined mean frequency (n) of scrums was 38.1 and no significant differences were observed between either of the groups of forwards. The combined mean relative time (%) spent scrummaging was 3.82 and there were no significant differences between FRF and BRF.

Roberts et al [40] had static exertion activities categorised as scrums, rucks, mauls, line-out lifts and tackles. In that study, mean frequency (n) of all the combined activities defining static exertions was significantly greater for the forwards than reported for the back players (89±21 *vs*. 24±10, $P<0.05$). Also, the average duration (s) spent in any static exertion activity was significantly higher for the forwards (5.2±0.8) compared to 3.6±0.8 for the backs ($p<0.05$). Austin et al [28] analysed scrums, rucks and mauls combined together and compared the results between forwards and backs. The authors found that the combined mean relative time (%) was 11.5±2.5 for the forwards compared to 3.0±0.5 for the backs ($p<0.05$).

Other movement activities (tackling, lineout, lifting/static holds, jumping)

Duthie et al [57] assessed the number of individual movements performed by senior rugby players in terms of tackling, jumping and lifting. The authors found the combined mean frequency for tackling per single match game of rugby was not significantly different between the forwards (9±6) and the back players (11±7). However, in absolute numbers, the BRF engaged in tackles most frequently when compared to any other positional groups. Austin et al [28] and Deutsch et al [58] also shared similar findings of no significant difference between the two generic groups of forward and back players in the mean tackling frequency per game of rugby. Nevertheless, Deutsch et al [58] found variations between individual player positions with BFR and IBs being more involved in more tackles than FRF ($P<0.0125$). In a study conducted by Duthie et al [57], “jumping” and “lifting” were only observed for the forward players. The authors found no significant difference between FRF and BRF on the mean total frequency for jumping (7±7 *vs*. 5±6) and lifting (9±6 *vs*. 6±5). Deutsch et al [58] also found no significant differences in the mean frequency between forwards and backs and among FRF, BRF, IBs and OBs with regards to jumping.

Eaton and George [59] analysed "tackling" and "lineout" in terms of the quantity, time spent (s) and the relative time spent (%) for each of those activities. For each individual player, tackling activities were split in two: tackles made by the player and tackles sustained by the player. The authors showed that tackling is a common activity performed by all players. No significant differences were observed for the mean frequency of tackles performed or sustained between the forward and back players. These results are consistent with the findings of other studies [50, 64]. However, Eaton and George [59] showed that the loose-head forward tackled the most, with a mean (±SD) frequency of 13±6 and were followed by the scrum-halves (11±4). On the other hand, the scrum-halves sustained the most tackles with a mean frequency of 9±4 compared to any other position. In terms of the mean relative time (%) spent, the loosehead forwards spent more time tackling (0.66±0.24) and this was significantly larger than for props (0.38±0.12), IBs (0.45±0.12) and OBs (0.34±0.12) but similar to the mean relative time (%) spent by hookers (0.45±0.12), locks (0.47±0.11), and scrum-halves (0.62±0.19). Overall, no statistically significant differences were observed between the forwards and backs. Austin et al [28] failed to show any significant differences in the mean relative time (%) between forwards and backs (1±0 *vs*. 2.0±0). The authors also analysed static holds (lifts) for the forward players only and showed no significant difference in the mean absolute time taken for static holds (lifts) between the FRF and BRF. This finding was also consistent with the findings reported by Duthie et al [57].

2.5.4 Impact load data

Several studies investigated impact data (intensity, frequency, and distribution) for junior and senior rugby players [7, 50, 54, 60, 61, 62]. All these studies gathered impact data derived from an accelerometer integrated within the GPS devices. The software is designed to record an impact when the body load gravitational force (G) is greater than 5G force units [50]. All the studies used a similar classification system for impact intensity data with ranges between 5-10+ (G): 5-6G was classified as light impact (hard acceleration, deceleration, and direct contact); 6-6.5G as light-to-moderate impact (player collision, contact with the ground); 6.5-7G as moderate-to-heavy impact; 7-8G as heavy impact; 8-10G as very heavy impact and 10+G as severe impact. Tee et al [60] analysed and classified impact data differently from other studies into two main categories: >5G representing LI impact and >8G representing high HI impacts. Table 2-3 summarised results from selected studies reporting on the frequency of game impacts sustained by rugby players.

Table 2-3: Impact classification from selected studies

Player impact classification	Authors/references	Results on player positions	
		Forward players	Back players
Light impact (5-6G)	Cunniffe et al [61]	563	349
	Coughlan et al [7]	472	353
	*Suarez-Arrones et al [62]	501.6±106	382±129
Light-to-moderate (6-6.5G)	Cunniffe et al [61]	398	328
	Coughlan et al [7]	132	65
	Suarez-Arrones et al [62]	341.3±219	326±173
Moderate-to-heavy (6.5-7G)	Cunniffe et al [61]	143	55
	Coughlan et al [7]	66	48
	Suarez-Arrones et al [62]	161.6±107	54.3±28.9
Heavy (7-8G)	Cunniffe et al 61]	101	38
	Coughlan et al [7]	105	54
	Suarez-Arrones et al [62]	143.1±122	29.8±9
Very heavy (8-10G)	Cunniffe et al [61]	56	24
	Coughlan et al [7]	53	40
	Suarez-Arrones et al [62]	66.6±48	35.2±26
Severe (10+ G)	Cunniffe et al [61]	13	4
	Coughlan et al [7]	10	13
	Suarez-Arrones et al [62]	10.4±5	6.3±4
Total number of impacts	Cunniffe et al [61]	1274	789
	Coughlan et al [7]	838	573
	Suarez-Arrones et al [62]	n/r	n/r

*values are recorded as mean ±standard deviation; n/r=not reported explicitly

Overall, all rugby players receive a sizeable amount of light (5-6G) to severe (10+G) impacts during match games with positional differences between forwards and backs and between the individual positions. One of the first studies to evaluate the physical demands of rugby players using the GPS technology conducted by Cunniffe et al [61] with two senior elite rugby players (1 forward and 1 back) assessed the total number of impacts comparing between the forward and back player. Overall, the authors found that the forward player received a significant amount of impact compared the back player (1 274 *vs*. 798) during gameplay. Consequently, the total body load experienced by the forward player was relatively higher when compared to the total body load reported in arbitrary units (au) for the back player (31 402 *vs*. 119 103). Moreover, combining the game impacts in the three categories of heavy, very heavy and severe, the authors showed that the forward player was involved in 60% more high-level impacts than the back player. These findings suggest that forward players are subjected to a significant amount of impact in rugby matches when compared to the back players. In a similar case study of two rugby players (1 forward and 1 back player), Coughlan et al [7] also assessed the physiological load subjected to the players during various tasks. The authors specifically analysed scrums for the forward player and tackles made by and against the forward and the back player. Although all the two players sustained some degree of impact during the rugby match, the authors found that the forward player sustained a significantly higher number of impacts (838 *vs*. 575) and total-game body load (1486 *vs*. 952) when compared to the back player. However, these values were relatively lower than reported by Cunniffe et al [61] in a previous investigation.

Suarez-Arrones et al [62] also reported on impact data corresponding to each interval per position among 14 senior male rugby players. The authors found consistent results with the reports of other studies [7, 61, 50]. The mean frequency of the impacts decreased with increasing impact severity for both forward and back players in Suarez-Arrones et al [62] study. Overall, the forward players received a large number of impacts compared to the backs. Suarez-Arrones et al [62] combined game impacts of heavy, very heavy and severe and showed that forwards had an average impact of 220 compared to 71 for the backs per single match. Although statistically not significant, Coughlan et al [7] showed that back player had received severe impacts compared to the forward player. Similarly, Venter et al [50] reported that severe impacts were experienced by IBs (12.16±3.18) while FRF (8±4.58) had the least amount. On the contrary, Cunniffe et al [61] significantly showed that the forward player had more severe impacts compared to the back player. These findings were also shared by Suarez-Arrones et al [62]. Overall, these findings show that both back and forward players are predisposed to severe impact forces during rugby matches. Tee et al [60] studying the movement and impact characteristics of senior professional rugby players classified impact loads into low-intensity impact (>5G) and high-intensity impact (>8G). The authors found no significant differences in the total number of impacts between backs and forward players for both the low-and-high intensity impact categories.

2.5.5 Physiological responses during match play

2.5.5.1 Results on heart rate (HR) responses

Table 2-4 shows results from studies that provided within a match and/or training heart rate responses of junior and senior rugby players. Five (5) studies included in this review provided evidence on physiological demands of junior and senior rugby players based on the assessment and monitoring of heart rate (HR) [48, 49, 54, 61, 62]. According to Deutsch et al [49], HR data may be used as an indicator of work output largely due to the direct and linear relationship with oxygen consumption. Deutsch et al [49] showed that junior rugby players engage in activities throughout the match that causes the HR to operate in the sub-maximal zone (low heart rates) to maximal zone (maximal heart rates). This probably reflects the intermittent nature of the sport which is characterised by periods of short periods of HI work such as sprinting and long periods of LI work such as walking. Overall, the young players spent a greater percentage of time with the HR within the "anaerobic threshold" (moderate heart rates) and "supra-threshold zone" (high heart rates). Comparing between forwards and backs, the relative time (%) spent in "maximal exertion" (>95% HR_{max}) showed no significant differences between positions, although the forward players had slightly higher absolute values compared to the backs. The forward players were, however, shown to spend significantly greater relative time (%) in "high exertion" (85-90% HR_{max}) as compared to the back players. On the other hand, the back players were found to spend a significantly higher relative amount of time (%) in "moderate exertion" when compared to the forward players.

Cunniffe et al [61] also monitored and collected data on the HR of the two players to understand the physiological demands of elite rugby players. The two players recorded mean and peak heart rates of

172 and 200 beats per minute respectively. Although the classification of HR was slightly different from the categories used previous in a TMA by Deutsch et al [49], the authors found that both players reached the pre-established maximum HR (HR_{max}) during the game of rugby. The back player was, however, shown to spend more percentage time at 80 to 90% HR_{max} than the forward player (42.2% vs. 27.7%). On the other hand, the forward player was shown to spend more relative time (%) in activities with the HR at 95-100% HR_{max} (15.4 *vs.* 4.7). Suarez-Arrones et al [56] also monitored the HR of 14 elite rugby players and recorded mean and peak heart rates for the forwards of 158.1±8.1 and 186.8±10 beats per minute, respectively. The back players had slightly higher, but not statistically significant, mean and peak heart rates than forwards of 163.4 ±4.6 vs. 190.6±2.2 beats per minute, respectively. As observed in the previous investigations of Deutsch et al [49] and Cunniffe et al [61], Suarez-Arrones et al [62] study also found that all rugby players reached pre-established maximum heart rates during games. However, differences were observed for the relative time spent in maximum exertion (95-100% HR_{max}) between players, with the forward players spending more time in maximum exertion than backs. These findings are consistent with the findings of Cunniffe et al [61] and Deutsch et al [49]. The majority of the time was spent by the players, irrespective of position, in 80-90% HR_{max} zone. The forward players showed higher percentage values in the heart zone as compared to the back players. This finding contradicts the results reported by Cunniffe et al [61] who showed significant differences with the back player spending relatively more time in the 80-90% HR_{max} than the forward players.

Table 2-4: Heart rate monitoring for rugby players

Author	Level	Method of analyses	Results
Deutsch et al. [49]	Junior players	<u>HR classification</u>	<u>Study findings per classification</u>
		Maximal (>95% HR_{max})	No significant differences in the mean percent time spent in maximal heart zone among FRF, BRF, IB and OBS
		Supra-threshold (85-95% HR_{max})	Forwards (FRF and BRF) spent significant mean percent time in supra-threshold heart rate zone than back players
		Anaerobic threshold (75-84% HR_{max})	Backs (IBs and OBs) spent significant mean percent time in moderate anaerobic heart rate zone than forward players
		Sub-threshold (>75% HR_{max}).	Backs spent significant mean percent time in sub-threshold heart zone than forwards
Cunniffe et al [61]	Senior players	<u>HR classification</u>	<u>Study findings per classification</u>
		Zone 1 (0-60 HR_{max})	Percent time per HR zone (back vs. forward)=0 vs. 1.8
		Zone 2 (60-70% HR_{max})	Percent time per HR zone (back vs. forward)=2.5 vs. 3.7
		Zone 3 (70-80% HR_{max})	Percent time per HR zone (back vs. forward)=13.9 vs. 15.7
		Zone 4 (80-90HR_{max})	Percent time per HR zone (back vs. forward)=42.2 vs 27.7
		Zone 5 (90-95HR_{max})	Percent time per HR zone (back vs. forward)=36.7 vs. 35.7
		Zone 6 (95-100% HR_{max})	Percent time per HR zone (back vs. forward)=4.7 vs. 15.4
Suarez-Arrones et al [62]	Senior players	<u>HR classification</u>	<u>Study findings per classification</u>
		Zone 1 (0-59.9% HR_{max})	Percent time spent in this zone was negligible for both players.
		Zone 2 (60-69.9% HR_{max})	Percent time spent in this zone was negligible but backs had slightly more time than forwards
		Zone 3 (70-79.9% HR_{max})	Backs spent more percent time in this zone than backs
		Zone 4 (80-89.9% HR_{max})	Most players (backs and forwards) spent relatively more percent time in this zone with figures for forwards slightly higher than that of backs.
		Zone 5 (90-94.9% HR_{max})	No significant difference between forwards and backs
		Zone 6 (95-100% HR_{max})	Forwards spent relatively more percent time in this zone compared to backs.
Portillo et al [48]	Junior players	<u>HR classification</u>	<u>Study findings per classification</u>
		Zone 1 (<60 % HR_{max})	No significant difference in percentage time spent within the zone.
		Zone 2 (60-70% HR_{max})	No significant difference between forwards and backs.

		Zone 3 (70-80% HR_{max})	No significant difference in percentage time between forwards and backs (23.2±11.2% vs. 28.5±6.5%, p=0.362, effect size=0.6)
		Zone 4 (80-90% HR_{max})	No significant difference in percentage time spent between forwards and backs (40.2±3.1% vs. 45.4±11.1%, p=0.365, effect size=0.73)
		Zone 5 (90-95% HR_{max})	Significant difference in percentage time spent between forwards and backs (21.2±10.2% vs. 12.4±3.3%, p=0.093; effect size=1.30
		Zone 6 (95-100% HR_{max})	No significant difference in percentage time spent within the zone.
Vaz et al [54]	Junior rugby players	<u>HR classification</u>	<u>Study findings per classification</u> Cluster 1=Under 16 players Cluster 2=Under 18 players
		Zone 1 (<75 % HR_{max})	Cluster 2 players spent significantly more time (minutes) in this zone than Cluster 1 (20 vs. 37)
		Zone 2 (75-84.9% HR_{max})	No significant difference in total time taken in this zone between cluster 1 and 2 (17 vs. 15)
		Zone 3 (85-89.9 HR_{max})	Significant difference between cluster 1 and 2 (10 vs. 5)
		Zone 4 (≥ 90 HR_{max})	Significant difference between cluster 1 and 2 (10 vs. 4).

HRmax =maximal heart rate

2.5.5.2 Results on blood lactate (BL) concentration levels

As shown in Table 2-5, Deutsch et al [49] showed that forward players had higher mean BL concentration levels when compared to the back players, albeit the lack of statistical significant difference (p=0.063). Also, the peak BL concentration levels were observed in the forward players but there were no statistically significant differences between the groups.

Table 2-5: BL concentrations for rugby players

Authors	Sample population	Method of analysis	Results on blood lactate concentration
Deutsch et al [49]	U19 junior rugby players	Blood sampled during rugby break. The blood samples were obtained from the earlobes once or twice during each half Blood samples analysed using portable reflectance photometry.	Forward players had higher mean BL concentration than backs (6.6 *vs.* 5.1mmol/litre; p=0.063). No significant differences observed in the peak BL concentrations between forward and backs and between the individual positions. But forward players had a higher absolute peak values of BL compared to the backs.

2.5.6 Implications on test battery design

The purpose of this review was to deduce the probable key physical or physiological requirements and rugby-specific game skills needed by rugby players considering the movement and physiological demands of the sport. The twenty-five (25) studies included in the review were mainly from NZ, Australia, England, SA and France. Also, most studies (n=17) assessed the match demands of senior-level rugby as opposed to junior rugby. These findings portray increased rugby popularity and massive investment in sport science research and continuous quest for knowledge to improve physical conditioning and testing programmes of elite senior rugby players in these countries. This review exposed varied methods of analysing physical and physiological match demands of rugby players from video-based TMA, automated multiple cameras, heart rate monitors, and blood lactate sample collections to modern devices such as GPS tracking software. However, despite study differences in methodology and technologies used, the overall impression is that rugby is an activity-filled sport characterised by player performances of multiple movement activities, tackles and discrete activities throughout the match.

Regardless of the level of competition, rugby players are known to spend 79% to 94% of match time in LIA interrupted briefly by moderate-to-high intensity running or non-running activities with no significant differences between the first and second half [48, 52, 61, 62]. All rugby players variably experience these sporadic intensities throughout the 70-80 minutes of match play and should have the qualities that prepare them to cope with the intermittent demands [50]. The specific movement patterns for each player in a typical rugby match occur on a wide spectrum from non-running LI activities such as standing, walking, lateral/ utility movements, to low-to-medium intensity running activities reported as jogging, cruising, and striding to HI running activities defined as high-speed runs or sprints.

Rugby match activities involve standing, walking and running (Figure 2-2). However, running occurs at different speed intensities from low to high and is interspersed with player involvement in rucking, mauling, tackling, lifting, kicking, and passing activities. The energy contributions during the work periods are primarily anaerobic [57] and aerobic during the recovery periods to replenish energy stores [61]. These findings point to the requirement of high anaerobic capacity to cope with the repeated intense efforts and aerobic fitness to cope with the influence of fatigue.

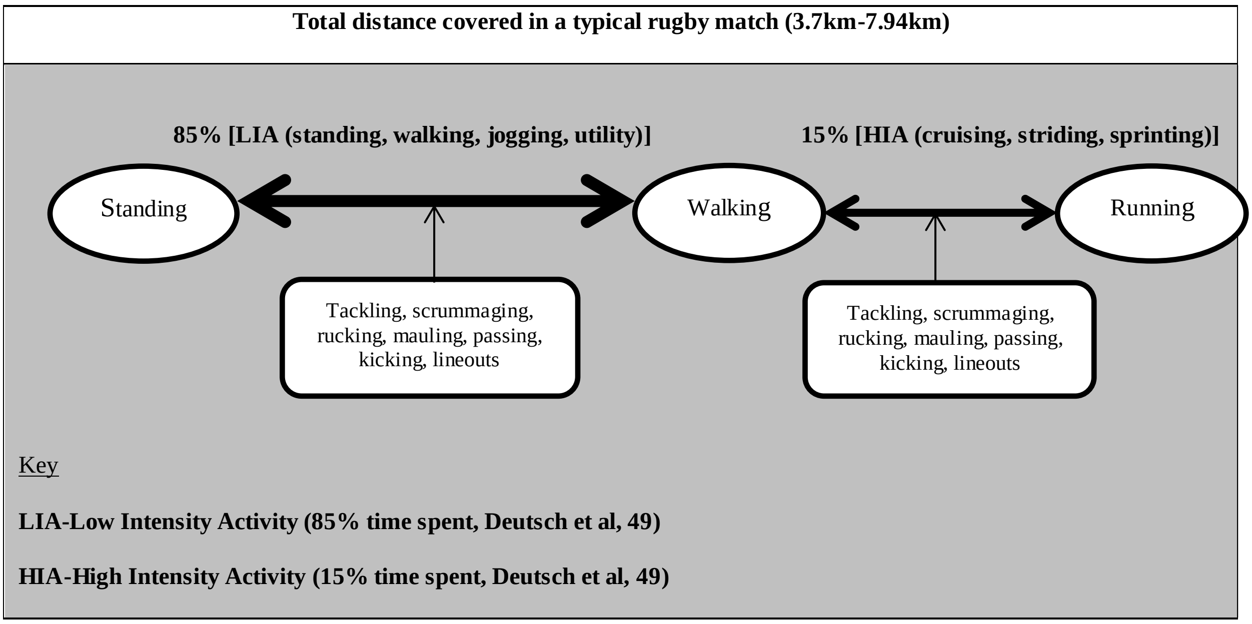

Figure 2-2: A schematic representation of movement activities

It is the short HIA that are most crucial in intermittent sports determining the outcome of matches in terms of winning or losing [64]. Accordingly, understanding the key characteristics and skills needed to repeatedly perform these intense activities should have important implications for test battery design. Static exertions (scrummaging, rucking and mauling) and power-based tasks such as tackling require high levels of upper-and-lower body muscular strength and power [28, 58, 57] and technical proficiencies in skill execution.

Sprinting efforts are key movement patterns commonly observed for both forward and back RU players [37, 45, 48, 54, 58, 62]. In a study by Deutsch et al [49], the maximum distance covered during sprints by young adolescent rugby players ranged from 17.0±6.0m for the BRF to 27.1±4.1m for the OBs. Suarez-Arrones et al [62] found that the average maximal distance (m) of a sprint ranged from 25.9±8.9 to 46.3±12.1 with mean sprint distances between 14.7±2.5m to 19.5±3.9m for all rugby players. Therefore, the testing of speed is important in rugby and should be over varied distances reflecting the maximum or mean speed requirements. With repeated efforts, both sprinting and HI static exertions such as rucking and mauling require some degree of endurance considering 70 or 80 minutes of match play [18, 51, 57, 61, 65]. Specifically, repeated sprinting ability (RSA) and repeated high-intensity exercise (RHIE) performance ability should be important components to include in test batteries designed for intermittent sports [66-71].

The current review showed that rugby players cover total distances between 3.70km and 7.94km for the entire 70-80 minutes of play. Although backs cover significant total distances than forwards, some studies showed no significant differences between forwards and backs in junior [48] and senior rugby [39]. Based on these findings, it is important to develop aerobic and anaerobic capacities of all rugby players to cope with the distances covered and the repeated HI activities common in rugby. Another category of discrete activities identified to be common in rugby involved kicking, passing, jumping and lifting indirectly suggesting important game-specific skills to the sport of rugby which are needed by all rugby players irrespective of position. Table 2-6 below summaries key review findings and implications towards understanding the qualities or skills important for rugby players.

Table 2-6: Implications of review findings on qualities or skills important in rugby

Major review findings	References	Summarised interpretation of findings	Qualities or skills relevant to rugby
Literature on match demands for junior rugby players came from adolescents playing competitive rugby in the U16 to U19 age categories.	[38, 48, 49, 58, 50, 54]	Competitive, professional and serious rugby likely to commence from the U16 henceforward.	Imperative for young adolescent playing U16 to U19 rugby to have i. Requisite qualities or skills commensurate with the level of competition.
The absolute total distances covered in match play by young male adolescent rugby players range between 3.79km to 5.75km.	[48, 49, 50, 51]	The physical demands of adolescent rugby are relatively high with young players covering relatively large distances in rugby matches	The distances covered suggest the need for i. Physical fitness ii. Player endurance.
Senior rugby players cover distances between 5.13km to 7.94km during a rugby match.	[40, 61, 28, 7, 44, 62, 18, 45, 39]	Senior players cover relatively larger distances compared to junior rugby players. The physical demands of rugby are higher in senior to junior rugby.	Need for progressive development and training of i. Physical fitness (endurance) to cope with increased demands at a higher level of competition.
No significant difference in the total distance covered during match play by adolescent rugby players between the back and forward players.	[48]	All adolescent rugby players cover similar match distances irrespective of player position	Possibly, all adolescent rugby players require i. Similar high endurance to sustain all rugby matches activities
Rugby players cover greater total distances during competitive match play than during training especially for young rugby players.	[79, 51]	Junior and senior rugby players cover greater distance in competitive matches than in training.	Need for training of i. Endurance to simulate adequately the match demands in both junior and senior rugby.
All rugby players irrespective of level of competition perform multiple movement patterns of LI and HI nature.	[40, 61, 28, 7, 44, 62, 18, 45, 39, 49, 51, 50, 48]	Rugby is an activity-filled sport characterised by intermittent performances of low and high intensity activities throughout the match for all the rugby positons.	All rugby players should be to i. Engage in LI and HI intensity match activities repeatedly throughout the match. ii. This may require a combination of aerobic and anaerobic capacities.

The majority of match play time is spent by rugby players in LIA. LIA includes movement patterns such as: standing/stationary, walking, jogging, lateral/utility movements	[49, 57, 59, 58, 40, 61, 28, 7, 51, 50, 62, 18, 63, 48, 45, 60, 55]	LI activities predominate in rugby for all rugby positions.	Standing/stationary reflects period of rest and recovery immediately after performance of HIA. Work periods are largely anaerobic. Walking, jogging and lateral movements are general movement patterns preparing the players for further engagements in medium and high-intense movement actions such as cruising, sprinting, tackling and static exertions from a position of readiness. All this suggests the importance of i. aerobic and anaerobic capacity ii. game awareness iii. alertness or game sense
HI intense activities common in rugby include running movement patterns of cruising striding sprinting and non-running static exertion patterns of tackling rucking mauling scrummaging	[49, 57, 59, 58, 40, 61, 28, 51, 50, 62, 18, 63, 45, 48, 60, 55, 52]	HI intense activities involves running, non-running based activities and discrete activities	These HI activities require rugby players to have i. running ability ii. sprinting ability iii. tackling ability iv. rucking ability v. mauling ability vi. muscular strength vii. muscular power Forward players should have i. Scrummaging abilities. The repeated nature of these HI activities further require i. prolonged running ability ii. repeated sprinting ability iii. speed endurance iv. repeated effort ability v. muscular strength vi. muscle power
The actual movement patterns in rugby occur on a wide spectrum from low-to-medium intensity running activities (jogging, cruising, and striding) to HI running activities (high-speed runs or sprints). This occurs throughout the match of rugby	[49, 57, 59, 40, 61, 7, 50, 62, 18, 63, 45, 48, 55, 38]	Running activities occur on a continuum from low-intensity running to high-intensity running	All rugby players require i. LI running ability ii. Prolonged LI running ability iii. HI running ability iv. Prolonged HI running ability v. Intermittent running ability vi. Prolonged HI intermittent running ability vii. Short duration repeated high intensity effort

			ability viii. Short duration repeated high intensity effort ability interspersed with low-intensity recovery effort
Discrete intense activities also commonly found in rugby and include lineouts lifting kicking jumping passing	[57, 59, 58, 40, 28]	Discrete movements common in rugby	All rugby players should have i. kicking ability, ii. tackling ability iii. jumping ability iv. passing ability The forward players also need additional i. lifting ability
Maximum sprint distance from a single sprint for junior and senior players ranged from 4.6±2.9m to 53.8±13.9m. However, the mean single sprint distances range between 5.71±4.5m to 23.6±1.2m	[49, 61, 48, 59]	Maximum sprinting distances vary in rugby (5-54m). Rugby players typically sprint between 6-24m.	Rugby players require sprinting abilities over short (<10m) and long distances (50m). Hence players require i. Short distance sprinting ability ii. Long distance sprinting ability iii. Short distance sprinting endurance iv. Long distance sprinting endurance v. Repeated sprinting ability
The combined mean frequency for tackling per single match game of rugby was not significantly different between the forwards and the back players	[57, 28, 49]	Tackling frequency similar for both forward and back players	All rugby players require to have i. Tackling ability
Overall, all rugby players receive a sizeable amount of light to severe impacts during match games with positional differences between forwards and backs.	[7, 61, 62]	All rugby players sustain impact during rugby matches	All rugby players require the following to counter or avoid impact loads i. Muscular strength ii. Evasion skills iii. Body mass iv. Body fat

2.6 Qualities discriminating players of intermittent contact team sports

There is inconclusive evidence on qualities or skills discriminating players of different intermittent contact team sports such as RU, RL and AFL [70, 72-81]. Such studies enhance understanding of the possible qualities or skills of relevance to the sport of rugby requiring further training for effective participation or performance. However, population, methodological and sport differences probably explain differences in the results obtained for the reviewed studies. Appendix B provides detailed results from selected studies conducted between 2006 and 2016. However, Table 2-7 below further synthesises the information from Appendix B and provides a summary of the qualities or skills found in selected studies to be discriminating athletes of contact team sports such as RU and RL by age or playing abilities.

Table 2-7: Summary of key results from selected studies

Author	Sport	Sample	Qualities/ skills found discriminating players of different playing abilities or age categories
Gabbett [82]	RL	Adults	Age, playing experience, body mass
Durandt et al [72]	RU	Adolescents	Height, body mass, upper-body absolute strength, upper-body relative strength, and aerobic endurance
Gabbett et al [74]	RL	Adults and adolescents	Age, playing experience, ball carrying skills, skills under fatigue, evasion skills, and defensive skills
Gabbett et al [75]	RL	Adults	Speed, and reactive agility
Baker [76]	RL	Adults	Absolute upper-body strength endurance
Spamer et al [77]	RU	Adolescents	Mass, skinfold measures, agility, speed, muscle flexibility, lower-body muscular power, upper-body muscular endurance, ground skill ability, side-step ability, air-and-ground skills, passing-for-distance
Spamer and De la Port [73]	RU	Adolescents	Mass, sum of skinfolds, speed, speed endurance, upper-body muscular strength, catching ability, and passing-for-accuracy
Gabbett [83]	RL	Adolescents	Height, mass, sum of skinfolds, maximal aerobic power, speed, change of direction speed, lower-body muscular power
Gabbett et al [78]	RL	Adolescents	Mass, speed, change of direction speed, lower-body muscular power, tackling proficiency
Green et al [20]	RU	Adults	Speed, agility or change of direction speed, reactive agility test
Argus et al [43]	RU	Adults and adolescents	Age, mass, training age, absolute and relative upper-body muscular strength, absolute and relative lower-body muscular strength, and absolute and relative upper-body peak power
Waldron et al [84]	RL	Adolescents	Maturity, mass, skinfolds, lower-body muscular power, maximal aerobic endurance
Darrall-Jones et al [79]	RU	Adolescents	Age, height, mass, skin folds, lower-body muscular power, absolute and relative lower-body muscular strength, absolute and relative upper-body muscular strength, agility
Johnston et al [85]	RL	Adolescents	High-intensity intermittent running ability
Krause et al [86]	RU	Adolescents	Height, mass, body mass index, speed, lower-body muscular power
Till et al [87]	RL	Adolescents	Age, height, sitting height, mass, speed, upper-and-lower body muscular power, endurance
Gaudion et al [80]	AFL	Adolescents	Mass, lower-body muscular power, agility, speed, repeated sprinting ability, maximal aerobic capacity, athletic movement ability,
Kobal et al [81]	RU	Adults and Adolescents	Mass, lower-body muscular power, agility, speed, aerobic endurance
Jones et al [90]	RU	Adolescents	Body size, upper-body muscular strength, running momentum, speed, aerobic fitness

In a study describing differences in body composition, strength and speed characteristics between elite junior U16 and U18 SA RU players, Durandt et al [72] found that U18 rugby players had superior anthropometric measures of height and body mass. However, there were no statistically significant differences in sum of seven skinfold measurement ($p=0.51$) and calculated percentage body fat between the two groups ($p=0.70$). In terms of the physical fitness parameters, the U18 rugby players showed higher absolute and relative one-repetition maximum bench press (1-RM bench press) measures compared to the U16. Upper-body strength was different with the U16 completing fewer push-ups than the U18 players ($p<0.01$). Also, the U16s performed fewer shuttles than the U18 group based on the multi-stage shuttle run test. Notable between groups similarities in test performances were observed for the 10m, 40m speed test and Illinois agility test.

In a cross-sectional study by Gabbett et al [74] designed to compare the physiological, anthropometric and skill characteristics of first grade (23.7±4.3 years), second-grade (24.4±5.0 years) and third grade (17.8±1.5 years) RL players, the authors found no statistically significant differences between the groups in all anthropometric and physiological characteristics assessed ranging from mass, height, speed, agility, lower-body muscular power and maximal aerobic power. However, first-grade players had better ball carrying and evasions skills ($p<0.05$) compared to other groups. Additionally, first-grade players performed significantly better in basic passing and defensive skills than third grade players ($p<0.05$). No statistically significant differences were observed between groups for catching ability, tackling and offensive skills.

In another study, Gabbett et al [75] found that first-grade RL players had significantly greater scores for 5m sprint test [$p<0.05$, ES(effect size)=0.68, moderate], 10m sprint test ($p<0.05$, ES=0.85, large), 20m sprint test ($p<0.05$, ES=0.75, moderate) and reactive agility test (movement time, $p<0.05$, ES=0.73, moderate) compared to lesser skilled second- grade players. No significant difference was observed for agility tests such as L-run tests (ES=0.28, small) and change of direction 505 tests (ES=0.28, small) and modified 505 test (ES=0.32, small).

Spamer et al [77] compared one group of elite NZ players (higher-skilled players, n=24) to two groups of elite SA U16 rugby players (lesser-skilled players, n=43 and n=21) concerning game-specific, physical abilities and anthropometric data. The NZ players outperformed either one or both groups of SA rugby players on sit-and-reach test (ES=0.02-0.9), vertical jump test (ES=0.3-0.9), zig-zag run (ES=1.1), 10m speed test (ES=0.5), 45.7m speed test (ES=1.1), flexed arm hang (ES=0.8). In terms of anthropometric variables, elite NZ players had higher scores for body mass (ES=0.4-0.9), skinfold measures such as triceps (ES=0.05-1.1), sub-scapular (ES=0.5-0.6), mid-axilla (ES=0.5), supra-spinal (ES=0.9), pectoral (ES=0.9-1.2), abdominal (ES=0.5-0.8), thigh (ES=0.3-1.2), and calf (ES=1.0-0.2) compared to the two SA group of players. However, the percentage of body fat was significantly reduced in elite NZ players compared to the SA players (ES=0.5-0.8). For the game skills, the NZ players had better scores for ground skills ability (ES=1.4-6.7) and air and ground skills (ES=1.0-1.3) compared to both the SA groups. There were small practical significant differences (ES≥0.4) between groups observed for passing-for-accuracy 4m and 7m tests (ES=0.1-0.4), kicking-for-distance test (ES=0.04-0.4) and kick-off distance test (ES=0.2-0.4).

Darrall-Jones et al [79] evaluated the anthropometric and physical characteristics of RU players playing at three distinct age categories from U16, U18, and U21. The authors found significant increases across the three age categories for height (p=0.002), body mass (p<0.001), countermovement jump height (p<0.001) and peak power (p<0.001), absolute and relative front and split squats (p<0.001), bench press (p<0.001), prone row (p=0.001 and chin (p<0.001). These findings hint to several qualities discriminating rugby players by age categories. However, the 5m speed test (p=0.677), 10m speed test (p=0.688), 20m speed (p=0.895) and 40m speed (p=0.085) tests failed to distinguish the rugby players by age categories.

2.7 Conclusion

Table 2-8 below represents a summary of qualities or skills identified as key requirements for rugby. Practically, these findings suggest attributes important for optimal participation in the sport of rugby and could be included in screening test batteries designed for the evaluation of potential rugby talent.

Table 2-8: Attributes known in the literature to be important for rugby

Attribute		*Identified qualities or skills
I.	Anthropometric characteristics	Body mass Lean body mass Height Body mass index Maturity
II.	Physical/physiological characteristics	Upper-body muscular strength Lower-body muscular strength Endurance Maximal aerobic capacity Anaerobic capacity Speed Momentum Speed endurance High-intensity intermittent running ability Prolonged high-intensity intermittent running ability High-speed running ability Prolonged low-intensity running ability Repeated sprinting ability Repeated effort ability Upper-body muscular power Lower-body muscular power Agility/Change of direction speed Muscle flexibility
III.	Rugby-specific game skills	Kicking ability Ball carrying skills Ball possession skills Skills under fatigue Evasion skills Reactive agility Ground skills ability Side-step ability Air-and-ground skills Passing-for-distance Catching ability Passing-for-accuracy Tackling proficiency Rucking ability Mauling ability Defensive ability skills Offensive ability skills Scrummaging Lifting ability skills Jumping ability skills Throwing ability skills Game alertness and sense

*collective synthesis of information gathered from match demand, description of rugby match play and discriminant validity studies expressing qualities or skills theoretically important for rugby players.

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3 CHAPTER 3: QUALITATIVE STUDY

3.1 Introduction

This chapter constituted the second part of Phase I. Following the narrative literature review which showed several variables possibly important in rugby (see Table 2.8) and would warrant inclusion in test battery design, a small-scale qualitative study using semi-structured interviews was conducted to determine whether local high school rugby coaches' would perceive the identified attributes as practically important for adolescent rugby or they would have different perceptions based on practical experience. Therefore, this chapter explored perceptions of schoolboy rugby coaches on the qualities and/or skills defining good male adolescent rugby players and are important for player recruitment in talent identification and recruitment programmes. From the interview guide, the coaches were questioned about the qualities and skills they perceive to be extremely important in an adolescent rugby player for have them to be considered a good player. A word-for-word research publication from BMC Research Notes is presented here as Chapter 3. Appendix C represents another full-text research publication that also emerged from the qualitative study exploring reasons for adolescent participation behaviour in competitive rugby and coaches selection criteria for player inclusion in school rugby teams.

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BMC Research Notes

RESEARCH NOTE

Open Access

Coaches' perceptions on qualities defining good adolescent rugby players and are important for player recruitment in talent identification programs: the SCRuM project

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Abstract

Objective: Competitive rugby is increasingly becoming popular among adolescent players even in countries hardly known for rugby such as Zimbabwe. Given the increased participation rates, burgeoning talent identification (TID) programs and the reportedly high injury-risk associated with competitive youth rugby, the minimal qualities or skills needed for effective performance by all young players need further clarification. Therefore, this qualitative study was conducted to explore the perceptions of high-school based rugby coaches on the key qualities or skills defining good adolescent rugby players and should be considered for player recruitment in TID programs. Currently, there is no consensus in literature from the coaches' perspective on these qualities.

Results: The final sample had 22 coaches (median age = 45.5 years) with years of coaching high-school rugby ranging from 6 to 17 years. Using the conventional approach to inductive content analysis four broad themes emerged suggesting the multifaceted nature of the requirements imperative for effective and optimal rugby performance among adolescent rugby players as perceived by the coaches. Themes identified included: physiological characteristics, anthropometric attributes, psychological qualities and game-specific skills. Possibly, training approaches or design of rugby-specific test-batteries should consider all these important qualities and be multi-dimensional in composition.

Keywords: Rugby, Perceptions, Qualities, Skills, Attributes, Qualitative study, Coaches

Introduction

Globally, the number of adolescents playing competitive rugby is increasing even in countries where rugby is still developing such as Zimbabwe [1–3]. Due to high injury risk associated with rugby [4–7], adolescents playing competitive rugby should possess qualities needed for competition. Rugby is a physically challenging sport requiring specialist training of participants in preparation of the physiological demands and sporadic intensities [8, 9]. Hence, coaches should ensure that young players have qualities commensurate with rugby demands [10–12].

The need for talented young rugby players is a long-term vision for many countries [13]. Consequently, rugby bodies are constantly developing models for early identification of athletes [14–16]. Furthermore, demand for knowledge on rugby requirements continues to stimulate research on qualities discriminating players [17–19]. Previous studies have shown that anthropometric, physiological, rugby-specific skills and psychological attributes either determine team selection or discriminate rugby players by playing abilities [20–23], indirectly suggesting qualities important for rugby. However, little is known whether rugby coaches' value these identified qualities

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3.2 Background

Globally, the number of adolescents playing competitive rugby is increasing even in countries where rugby is still developing such as Zimbabwe [1-3]. Due to high injury risk associated with rugby [4-7], adolescents playing competitive rugby should possess qualities needed for competition. Rugby is a physically challenging sport requiring specialist training of participants in preparation of the physiological demands and sporadic intensities [8, 9]. Hence, coaches should ensure that young players have qualities commensurate with rugby demands [10-12].

The need for talented young rugby players is a long-term vision for many countries [13]. Consequently, rugby bodies are constantly developing models for early identification of athletes [14-16]. Furthermore, demand for knowledge on rugby requirements continues to stimulate research on qualities discriminating players [17-19]. Previous studies have shown that anthropometric, physiological, rugby-specific skills and psychological attributes either determine team selection or discriminate rugby players by playing abilities [20-23], indirectly suggesting qualities important for rugby. However, little is known whether rugby coaches' value these identified qualities or have different perceptions based on practical and contextual experience. Currently, literature is equivocal on the qualities coaches perceive important or should be emphasised for training [24].

In Zimbabwe where high-school rugby is still developing and mainly played by schoolboys, it is interesting to explore what local coaches perceive as the most important qualities characterising good adolescent rugby players and are important when recruiting young rugby talent. Such studies potentially inform the composition of future test batteries designed for talent identification (TID) programmes. Therefore, the present study sought rugby coaches' perceptions on qualities defining a good adolescent rugby player and is important for consideration in player recruitment in TID programs.

3.3 Main text

3.3.1 Study design, setting and participants

A qualitative study design was employed to determine qualities characterising good adolescent rugby players from the coaches' perspective. This study was part of a project called the School Clinical

Rugby Measure (SCRuM) partly described elsewhere [25, 26]. The present study targeted coaches of high-school male adolescent rugby players in Zimbabwe and was conducted at a school hosting the 2017 Dairiboard Zimbabwe Schools Rugby Festival (DZSRF). The festival is an annual national youth rugby tournament featuring rugby-playing primary and secondary schools. Reportedly, 150 schools participated in the seven-day long tournament in 2017 [27]. The concept behind DZSRF is similar to the national youth rugby tournaments held in South Africa designed for U13 to U18 rugby players [28-31].

3.3.2 Sampling and eligibility criteria

The coaches were selected with an apriori intention of maximum heterogeneity within the sample. This entailed purposively-recruiting coaches from schools playing in the three high-school rugby leagues. The leagues include the Super Eight Schools Rugby League ("elite league"), Co-educational School Rugby League ("sub-elite") and the Interscholastic High Schools Rugby League ("amateur league") [26]. Firstly, a list of all participating high schools was obtained from the DZSRL director. The schools were then stratified into three categories representing the domestic high-school rugby leagues. Out of the 42 coaches approached from various schools, 22 volunteered to participate. The participants' demographic characteristics and rugby-related information are presented in Table 3-1. However, full-time rugby coaches with at least five years of U13 to U19 coaching experience were eligible. Additionally, coaches previously involved in TID programmes were purposively recruited for that unique experience.

Table 3-1: Sample demographic characteristics and rugby-related information (N=22)

Characteristic	Response	n (%)
Type of school coached	Government	10 (45.5)
	Private	12 (54.5)
*High-school rugby league the school plays in	Super Eight Schools Rugby League (elite)	11 (50.0)
	Coeducational Schools Rugby League (sub-elite)	5 (22.7)
	Interscholastic Schools Rugby League (amateur)	6 (27.3)
Age of the participants	30-39 years	3 (13.6)
	40-49 years	16 (72.8)
	50+ years	3 (13.6)
Median age (45.5 years) **Interquartile range**=42-49 years		
Number of years coaching high school rugby in total	≤ 9 years	16 (72.7)
	10+ years	6 (27.3)
School rugby team currently being coached	Under 13s	1 (4.5)
	Under 15s	2 (9.1)
	Under 16s	5 (22.7)
	Second team	5 (22.7)
	First team	9 (40.9)
Number of years coaching current school rugby team	1-2 years	7 (31.8)
	3-4 years	8 (36.4)
	5-6 years	3 (13.6)
	7-8 years	3 (13.6)
	9-10 years	1 (4.5)
Other rugby coaching experience	Yes	4 (18.2)
	No	18 (81.8)
Have played rugby in lifetime	Yes	22 (100)
	No	0 (0)
Years played rugby in total	1-9 years	3 (13.6)
	10+ years	19 (86.4)

*Super Eight Schools Rugby League represents the best high school rugby league in the country featuring eight top rugby playing high schools in the country. The league is regarded as the "elite" league. Co-educational Schools Rugby League represents the second most competitive league in the country (sub-elite) and the Interscholastic Schools Rugby League represent high school rugby league for the rest of the schools playing rugby in the county mainly composed of amateur players.

3.3.3 Procedure

Ethical approval was granted by the Human Research Ethics Committee (HREC) of the University of Cape Town (reference: 016/2016) (Appendix D). Participant identification and data collection were conducted between 30 April and 6 May, 2017, with at least two interviews scheduled per day. Coaches were directly approached by the first author seeking participation. A verbal explanation highlighting the rationale and study procedural issues were given. Potential participants were also left with information letters further detailing study purpose and methodology (Appendix E). Interview appointments would be set with the willing coaches, agreeing on the most convenient time and place for the interview.

On agreed dates, coaches would be invited to a quiet classroom specifically allocated for the interviews. Prior to the interviews, participants provided written informed consent (Appendix E) and were verbally assured that the information provided was confidential. Coaches' demographic and rugby-related information was elicited first. Subsequently, a trained research assistant conducted semi-structured face-to-face interviews in English since all participants understood and spoke the language. The interviews were based on a face-and-content validated English interview guide (Appendix F) specifically developed and pre-tested for this study. Participants were probed for clarity and elaboration when necessary. All the interviews were audio-recorded and lasted between 15 to 40 minutes.

3.3.4 Data analysis

For this article, we only analysed transcribed data from the second part of the interview guide. The interview data were transcribed verbatim by an independent person. Subsequently, the transcripts were proof-read by the first author against the original audio material verifying transcription accuracy. Noted discrepancies were discussed with the interviewer and transcriptionist for a mutual consensus. Participant checking of the transcripts was then conducted with a convenience sample of rugby coaches (n=12). Data analysis commenced immediately after member checking. The manifest and latent content of the transcriptions were analysed according to the conventional approach of inductive content analysis to generate categories and themes [32-34]. Conventional content analysis is commonly used to analyse textual data preferably when literature on a phenomenon is limited [32]. Literature documenting coaches' perceptions on qualities defining good adolescent rugby players is sparse. Content analysis of textual data was manually conducted by the first author following steps of decontextualisation, recontextualisation and categorisation as described in the literature [35]. A summary of the analytical process is provided in Figure 3-1 below.

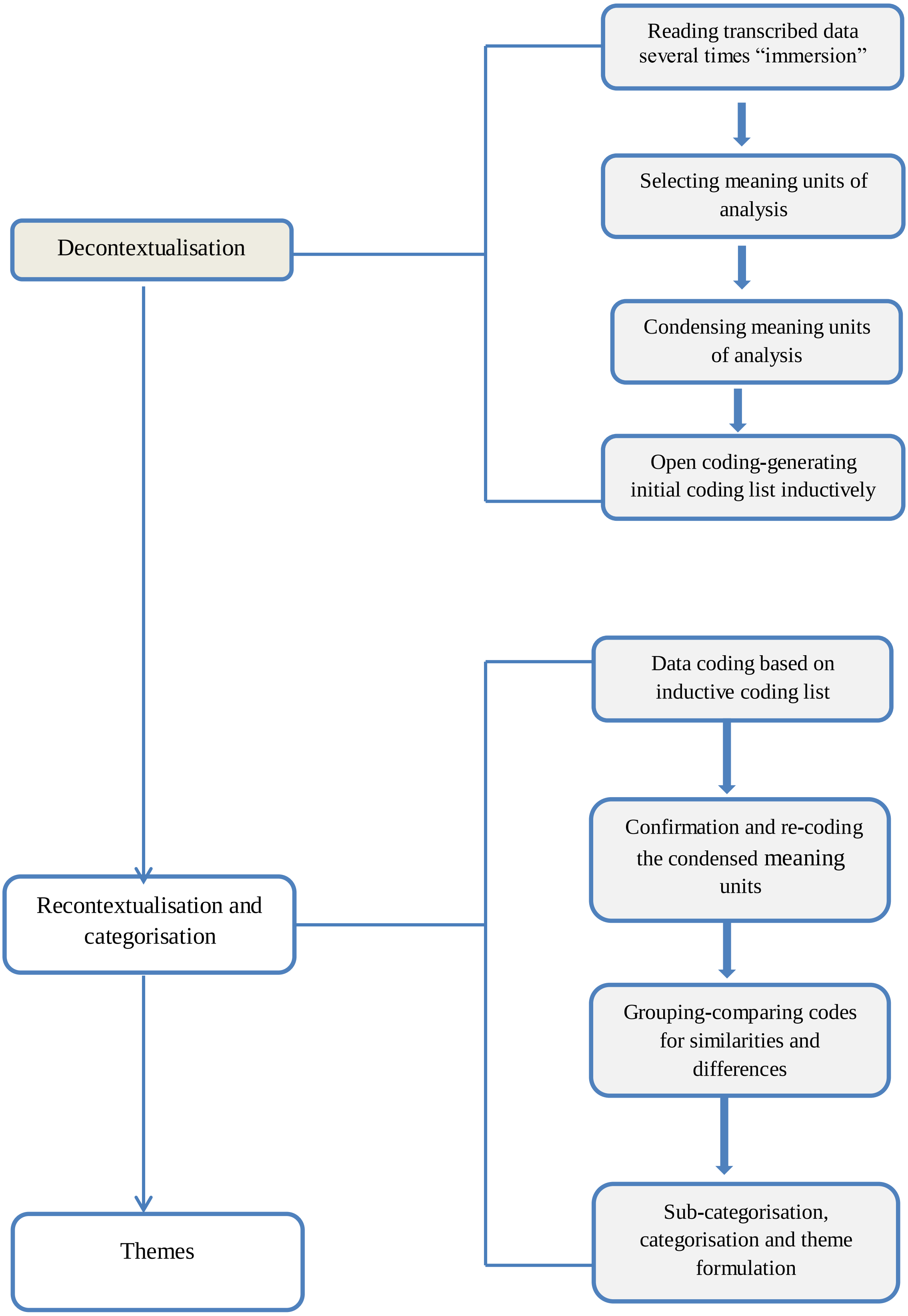

Figure 3-1: Summary of the content analysis process

3.3.4.1 Decontextualisation

Firstly, the first author read several times the entirety of transcribed data. This process of "immersion" was to gather a general understanding of the data [32, 34-36]. Then, each transcript was carefully read specifically highlighting sentences or phrases (*meaning units*) expressing qualities defining good rugby players. The highlighted meaning units were then "copy-pasted" onto a new document and further condensed into smaller meaning units, called *condensed meaning units* [34, 35]. The next step involved inductively creating an initial code list from the condensed meaning units of three randomly selected transcripts in a process called *open-coding* [32, 37]. This process was done to minimise the change of the codes during the process of coding the rest of the transcripts [35]. Using the generated code list as a guide, the first author then coded the rest of the 19 transcripts and adding new codes when necessary [32].

3.3.4.2 Recontextualisation and categorisation

After coding, the first author read several times the meaning units, condensed meaning units and emergent codes to confirm or re-code the condensed meaning units. Subsequently, the researcher "copy-pasted" all the emergent codes onto a Microsoft Excel document, comparing the codes for possible similarities and differences [36]. Similar codes were coalesced and different codes remained distinct. Codes were then sorted into sub-categories and furthermore, into categories for the manifest content. Finally, the underlying meaning of the categories representing the latent content of the data was examined generating themes [36]. Although coding was undertaken by the first author, investigators' triangulation was conducted to validate the process. This was done by having the second (NM) and third authors (SO) code the transcriptions independently and derive own categories and themes. The authors (MC, SO, NM) had to compare the coding, sub-categorisation, and categorisation, discussing reasons for developed themes. Differences were solved by revisiting textual data, derived meaning units and condensed meaning units, and mutually re-coding the data, and agreeing on appropriate sub-categories, categories and themes.

3.4 Results

The four major themes representing qualities defining good adolescent rugby players and are important for player recruitment in TID programs that emerged from the coaches perceptions were: *(i) "physiological characteristics"*, *(ii) "anthropometric attributes", (iii) "game-specific skills", (iv) "psychological qualities"* (Table 3-2). Appendix G further depicts emergent codes and illustrative quotes from selected coaches in detail.

Table 3-2: Results of thematic analysis of coaches perceptions (N=22)

Theme	Category	Sub-category
Physiological characteristics	Muscular strength	Total body strength
		Upper-body muscular strength
		Lower-body muscular strength
	Muscular power	Total muscular power
		Upper-extremity power
		Lower-extremity
	Agility	Agility
	Endurance	Endurance
	Speed	Speed
		Repeated running
	Anaerobic capacity	Anaerobic capacity
	Balance	Balance
	Coordination	Coordination
	Muscle flexibility	Muscle flexibility
	Repeated effort ability	Repeated high intensity effort
Anthropometric variables	Physical qualities	Body mass
		Height
		Body composition
Game-specific skills	Basic technical skills	Passing
		Kicking
		Catching
		Tackling
		Evasion
		Ball handling skills
		Defensive/offensive skills
	Perceptual-cognitive skills	Auditory skills
		Visual skills
		Anticipatory skills
		Decision making
		Game sense
		Adaptability
	Miscellaneous	Communication skills
		Leadership
		Competitiveness

		Team player
Psychological qualities	Mental strength Emotional stability Attitude and personal traits	Mental strength Emotionally stable Positive attitude Courageous Determined Disciplined Teachable Passionate

3.5 Discussion

The present study revealed ten categories under physiological qualities, confirming findings from previous studies that rugby requires possession of many physiological qualities [17, 24]. Muscular strength and power were perceived to be crucial in match situations involving aggressive contact, lifting, tackling, running and scrummaging. Rugby is a full-contact sport warranting optimal muscular strength and power [38-40]. There is compelling evidence that muscular strength and power discriminate rugby players for team selection [41-43]. Endurance and anaerobic capacity were also perceived to be important. The coaches felt that rugby players should show excellent recovery after repeated engagements in physical episodes. This is because rugby is an intermittent sport characterised by high-intensity anaerobic activities separated shortly by low-intensity aerobic activities and rest [12, 44, 45]. Elite junior rugby league players were previously found to have superior maximal aerobic capacity when compared to sub-elite players [46, 47]. Speed, aerobic capacity, muscular endurance, and body mass predicted players selected for junior rugby teams [23]. In the present study, coaches' perceived speed as important and emphasised the importance of running ability. There is evidence correlating speed and repeated-sprint ability to game performance such as tackle breaks and tries scores [19]. Also, previous studies illustrated the importance of speed and agility [46, 47].

Anthropometric qualities such as appropriate height and optimal body mass were also perceived as important. In support, significant differences were found in body mass and composition between U14 rugby players playing competitive rugby compared to those playing at a more recreational level [43]. Skin-fold thickness significantly contributed to the discriminant analysis of selected and non-selected players in professional rugby league [41]. In a study observing changes in body size and anthropometric characteristics of U20 rugby players, Lombard et al [48] found that players became heavier and taller over time. Also, Darrall-Jones et al [20] demonstrated significant increases across age categories for body mass and height. These findings reflect the nature of the sport which emphasises appropriate anthropometrics attributes for rugby players [21, 22, 49, 50].

Coaches also perceived passing, catching, tackling and ball-handling skills as important. These findings were also shared by other authors [39, 51-53]. Additionally, the coaches perceived that perceptual-cognitive skills including decision-making ability, game-sense awareness, anticipation, visual and auditory skills were important. Hendricks [39] reported almost similar findings. Professional rugby league players had better tackling proficiency, pattern recall (ability to read the game) and prediction ability (decision-making), and reactive agility when compared to semi-professional players [54, 55]. Moreover, measures of technical and perceptual skills were associated with more line-breaks assists, try assists, and tackles completed during competition [56].

In the present study, psychological qualities were also perceived to be important although there are limited studies corroborating this evidence. Tredrea et al [23] found no significant differences between selected and non-selected adolescent players for psychological attributes using the Mental Toughness (MT) Questionnaire. However, other studies involving adult players reported contrasting results using the same tool [57]. Tredrea et al [23] attributed that to the reduced discriminative ability of MT tool in adolescents. Nevertheless, Larkin and O'Connor [58] found that perceived qualities such as "coachability" and "positive attitude" were important in soccer, an intermittent team sport like rugby. These findings were also shared by the coaches in the present study. The coaches felt that adolescent rugby players should be "teachable" and have personal attributes such as courage, determination, hardworking, discipline and passion for the sport.

In conclusion, coaches perceived physiological, anthropometric, and psychological and game-specific skills to be defining good adolescent rugby players. Therefore, training approaches or test-battery design should incorporate all these important qualities. Additionally, consistent with the training periodisation approach [59], coaches may utilise this information during the coaching process and in improving player performance.

3.5.1 Study limitations

- Although generalisation of study findings is not important in qualitative studies, the 22 participants represented all the high-school rugby leagues in the country. Nevertheless, one major limitation was that data analysis was not conducted iteratively based on the saturation concept.

- Investigator triangulation of the coding process conducted provides credibility to the findings. However, credibility could have been enhanced by eliciting the perceptions of male adolescent rugby players' playing competitive school rugby and further, ensuring that member checking of the transcripts involved not only a convenience sample of 12 rugby coaches as used in the present study.

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4 CHAPTER 4: FIRST SYSTEMATIC REVIEW

4.1 Introduction

The narrative literature review produced a list of theoretical variables representing anthropometric attributes, physiological characteristics and rugby-specific game skills important in rugby. In addition, the qualitative study explored coaches perceptions on the key requirements of adolescent rugby based on practical experience. Subsequently, this chapter constitute the third part of Phase I and was designed as a systematic review. The broad objective of the systematic review was to identify from the literature commonly-evaluated physiological characteristics and their corresponding tests in rugby and related intermittent contact team sports such as rugby league. Furthermore, we evaluated the measurement properties of each identified physiological tests. This chapter presents a research publication[3] that emerged from the conduction of the systematic review. The review paper was based on a published systematic review protocol (see Appendix H). Due to the unanticipated large volume of data found during the literature search, the protocol was split into two distinct reviews. The first systematic review on tests for physiological characteristics commonly-evaluated in rugby will be presented in this chapter.

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A systematic review investigating measurement properties of physiological tests in rugby

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Abstract

Background: This systematic review was conducted with the first objective aimed at providing an overview of the physiological characteristics commonly evaluated in rugby and the corresponding tests used to measure each construct. Secondly, the measurement properties of all identified tests per physiological construct were evaluated with the ultimate purpose of identifying tests with strongest level of evidence per construct.

Methods: The review was conducted in two stages. In all stages, electronic databases of EBSCOhost, Medline and Scopus were searched for full-text articles. Stage 1 included studies examining physiological characteristics in rugby. Stage 2 included studies evaluating measurement properties of all tests identified in Stage 1 either in rugby or related sports such as Australian Rules football and Soccer. Two independent reviewers screened relevant articles from titles and abstracts for both stages.

Results: Seventy studies met the inclusion criteria for Stage 1. The studies described 63 tests assessing speed (8), agility/change of direction speed (7), upper-body muscular endurance (8), upper-body muscular power (6), upper-body muscular strength (5), anaerobic endurance (4), maximal aerobic power (4), lower-body muscular power (3), prolonged high-intensity intermittent running ability/endurance (5), lower-body muscular strength (5), repeated high-intensity exercise performance (3), repeated-sprint ability (2), repeated-effort ability (1), maximal aerobic speed (1) and abdominal endurance (1). Stage 2 identified 20 studies describing measurement properties of 21 different tests. Only moderate evidence was found for the reliability of the 30–15 Intermittent Fitness. There was limited evidence found for the reliability and/or validity of 5 m, 10 m, 20 m speed tests, 505 test, modified 505 test, L run test, Sergeant Jump test and bench press repetitions-to-fatigue tests. There was no information from high-quality studies on the measurement properties of all the other tests identified in stage 1.

Conclusion: A number of physiological characteristics are evaluated in rugby. Each physiological construct has multiple tests for measurement. However, there is paucity of information on measurement properties from high-quality studies for the tests. This raises questions about the usefulness and applicability of these tests in rugby and creates a need for high-quality future studies evaluating measurement properties of these physiological tests.

Trial registrations: PROSPERO CRD 42015029747.

Keywords: Reliability, Validity, Responsiveness, Physiological characteristics, Rugby, Systematic review

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4.2 Background

Rugby (either rugby union or league) is a popular sport played professionally or otherwise at both junior and senior levels worldwide [1]. It is generally considered a physical sport characterised by multiple high-intensity activities interspersed with low-intensity activities [2-5]. The players engage in physically demanding contests such as tackles, rucks and mauls with the primary objective of gaining possession of the ball [6]. These contests require players to possess a wide range of physiological characteristics such as strength, power and endurance which allows them to be stronger and fatigue-resistant [7-10].

There are numerous studies in the literature that have provided scientific evidence on the physiological characteristics of rugby players. This has been necessitated by the drive to understand the physiological factors that differentiate between playing levels (talent identification) and the physiological characteristics associated with optimal performance [1, 2, 7, 10-18]. For example, Gabbett and Seibold [15] postulated that lower body power, upper-body strength-endurance, and prolonged high-intensity intermittent running ability discriminated players for team selection in semi-professional rugby league (RL) players. Smart et al [17] found correlations between speed, repeated-sprint ability and game performance statistics such as tackle breaks and tries scored in rugby union (RU). Furthermore, Till et al [18] compared longitudinal changes in physical qualities with career attainment status and found that advanced physical qualities such as absolute strength during the adolescence period contributed significantly to the attainment of professional status in rugby. All these findings suggest an important relationship between physiological characteristics and future career success, physical performance and team selection [15, 17, 18].

Today, physiological profiling of rugby players has become an integral aspect of the contemporary sport of rugby. It allows coaches to determine “competent” players with enhanced physiological capacities to withstand the high-intensity demands of the sport and can win trophies for team, club or country [6, 7]. This forms the hallmark of talent identification programmes. Secondly, understanding the physiological qualities needed in the sport of rugby may specifically inform training development practices of future professional players [18]. With the surge in physiological profiling, the proliferation of talent identification and development programmes for young rugby players [18], there is the need for identification and use of physical tests with known measurement properties (reliability, validity and responsiveness). A scoping review of the literature showed that there are multiple tests available for measuring the same physiological characteristic. For example, agility is a fundamental physiological characteristic required for optimal performance by rugby players. The construct has been evaluated using different tests such as 'L' run, Illinois agility run test, agility 5-0-5 test, modified 5-0-5 test and change of direction speed test in the literature [6, 10, 16, 18-22]. In an attempt to understand the basis of selecting tests, it may be important to have an overview of all the tests that measure a specific physiological construct and evaluate systematically the measurement properties of the identified tests in an attempt to identify test(s) with the strongest level of evidence per construct. Possibly, this information can help us understand the reasons for the selection of particular tests for the measurement of a specific physiological characteristic in terms of measurement properties. To our knowledge, there is no systematic review that has been conducted to provide such information. Therefore, this systematic review was conducted with the aim of addressing the following research questions:

1. What physiological characteristics of rugby players are evaluated in the literature and which tests are used to measure each identified characteristic?

2. What is known about the measurement properties (reliability, validity and responsiveness) of each identified physiological test in the sport of rugby? If there is no information on the measurement properties for each test in rugby, is there any evidence available from other closely-related intermittent, collision team sports to rugby such as Australian Rules football, American football or Soccer? In the case of multiple tests measuring the same construct, which test(s) has the strongest level of evidence in terms of the measurement properties?

4.3 Stage 1: Methods

4.3.1 Study design

This systematic review was registered on PROSPERO with the registration number CRD 42015029747 [21]. This review paper was organised in stages. Stage 1 presents an overview of the physiological characteristics commonly evaluated in rugby and the corresponding tests. Stage 2 presents an overview of the measurement properties of the identified physiological tests. Each stage was written in accordance with the Preferred Reporting Items for Systematic review and Meta-analyses (PRISMA) guidelines by Moher et al [23].

4.3.2 Literature search

A literature search was conducted using the following databases: *Scopus*, *Medline via EBSCOhost and via PubMed, Academic Search Premier via EBSCOhost, CINAHL (Cumulative Index of Nursing and Allied Health) via EBSCOhost and Africa-Wide Information via EBSCOhos*t. The review included studies published in the last 20 years between January 1, 1995, and December 31, 2016. Additionally, a hand search was also conducted on reference lists of selected articles to augment the literature.

4.3.3 Selection criteria for the studies

4.3.3.1 Sports context

There are two major variants of rugby, namely, RU and RL. Although RU differs significantly from RL in team sizes, scoring and in certain situations of tackling and when the ball goes out, there are striking similarities in game duration, field size, player positions, and goal posts [24]. There are also similarities in the physical demands and physiological responses elicited during gameplay as both sports are predominantly aerobic in nature interspersed with high-intensity efforts [5, 24]. The objective in both is to get the ball over the opposition's goal line by carrying, passing, kicking and grounding the ball. Therefore, because of the resemblance, we included studies on RU and RL. However, studies on the sport of rugby "sevens" were excluded.

4.3.3.2 Physiological characteristics

Rugby requires a blend of physiological characteristics for players to cope with the demands of the game [1]. The studies included had to report on at least one physiological characteristic operationally defined as measures that assess speed, repeated-sprint ability, prolonged high-intensity intermittent running ability, agility, muscular strength, power and endurance and maximal aerobic capacity. In addition, for studies to be included they had to report the name of the test used to measure the physiological construct and include a detailed, reproducible description of the test procedure. There was no restriction in study design applied during study selection. However, editorials, book chapters, poster and oral conference abstracts, unpublished theses, dissertations, and case studies were excluded. Studies published in non-English language were also excluded.

4.3.3.3 Participants

Since rugby is played competitively at junior and senior levels worldwide, studies included in this review had to involve male rugby participants from the age of 10 years and above (adolescents to adults) from any country. Studies involving rugby participants living with disabilities were excluded.

4.3.4 Search strategy

The search strategy was developed in consultation with an expert librarian in systematic reviews from the University of Cape Town (UCT) libraries. The search strategy (see Appendix I designed for Medline *via* PubMed) consisted of a combination of the following search themes connected with the Boolean terms AND:

i. Construct-related general search terms: *physical characteristics* OR *physiological characteristics.*

ii. Construct-related specific search terms: *speed* OR *agility* OR *flexibility*.

iii. Target population-related search terms*: adult* OR *adolescen*t OR *youth*.

iv. Sport-related search terms: *rugby* OR *rugby union* OR *rugby league*.

4.3.5 Selection of articles

The selection process was conducted stepwise based on recommendations for performing systematic reviews by van Tulder et al [25] and Reimers et al [26]. The first author ran the search strategy across all databases. Two reviewers independently reviewed the search results in two steps. The first step involved applying the inclusion criteria to select potentially relevant articles from titles. The abstracts of studies with titles considered relevant were retrieved for further inspection in the second step [26]. Provided that the abstract fulfilled the eligibility criteria or had insufficient information for a selection decision to be made, both reviewers retrieved the full text to further assess for eligibility [26]. Initially, disagreements among reviewers were discussed among themselves at the end of the selection process. In the case of further disagreements, a third reviewer intervened until a mutual consensus was reached. In addition, all retrieved articles were then reviewed again against the inclusion criteria by the lead investigator.

4.3.6 Data extraction

Data extraction was performed by two independent people. Extracted data was documented onto a Microsoft Excel data extraction form. The following data were captured for the first objective: (*i*) publication details of the study (first author, year of publication), *(ii)* the name(s) of the physiological characteristic examined in the study (captured as originally described by the authors) and the *(iii)* name of corresponding test(s) as described in the study used to measure the physiological characteristics. To enable the description of studies, additional information on sport contexts, age of participants, country, target population, study design and sample size were also extracted. The primary author acted as the data verifier, assessing the exhaustiveness and accuracy of data extracted from the included articles. Discrepancies in data extracted identified by the verifier were communicated to the two data extractors and disagreements resolved by mutual consensus.

4.3.7 Results: Stage 1

Since Stage 1 results were used to inform the methods and selection criteria for studies in the second stage of the systematic review, results for Stage 1 were presented here. The electronic searches revealed 23 976 studies and after initial selection based on abstract and title, 1 909 studies were potentially eligible (Figure 4-1). After full-text evaluation, 70 studies were included. The majority of the studies did not meet the inclusion criteria because they did not report on physiological characteristics (Figure 4-1).

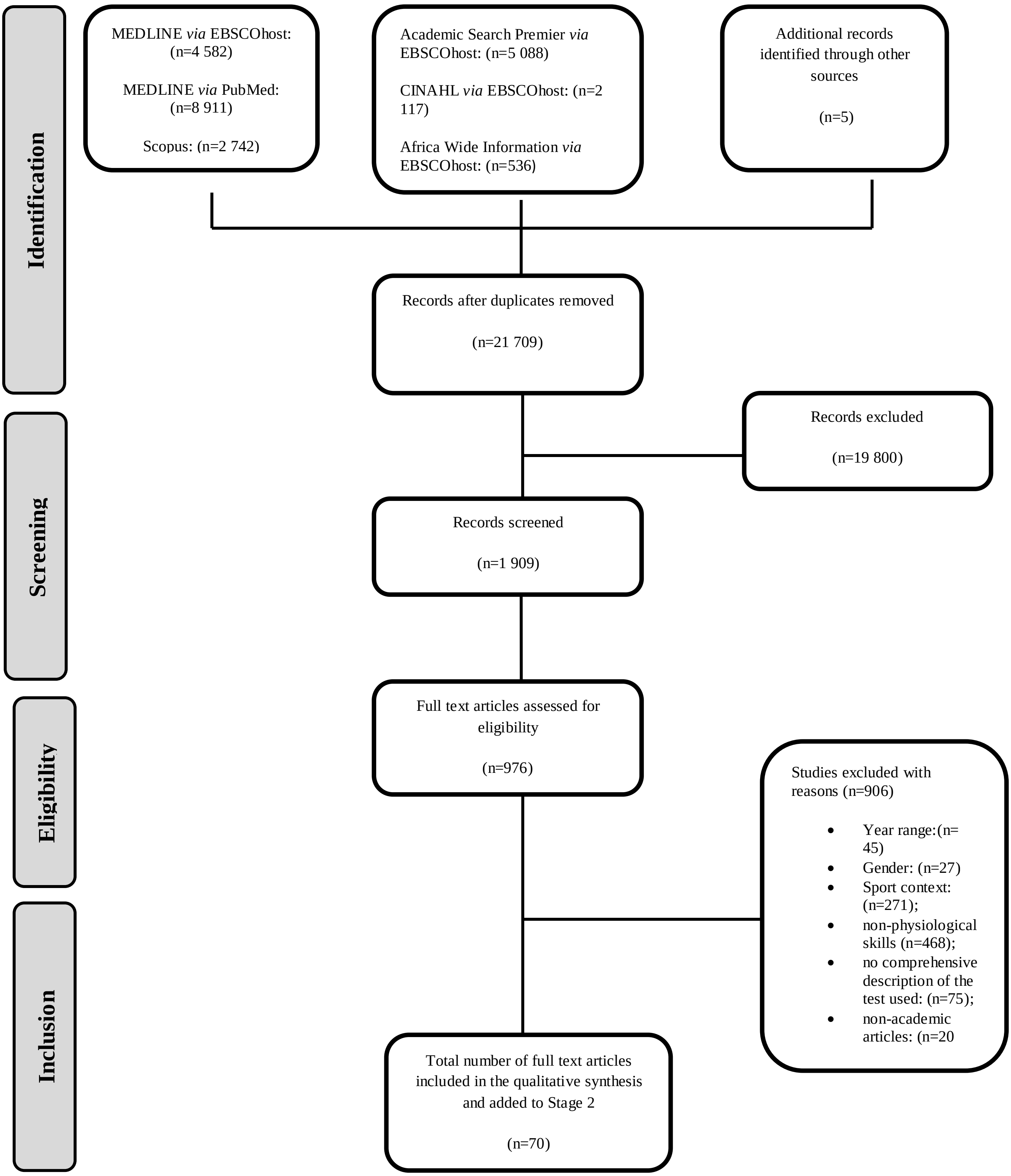

Figure 4-1: Flow chart of the search and selection process for Stage 1 articles

4.3.7.1 Description of included studies

The general characteristics of the 70 included studies are shown in Appendix J. Briefly, the majority of the included studies (n=35, 50.0%) were conducted in Australia alone. Only three (4.29%) studies were conducted in an African country, namely, South Africa [7, 27, 28]. Of the 70 studies, 34 (48.6%) had adolescents as participants and six (8.57%) used both adults and adolescents. The sample sizes varied greatly across studies from 12 to 1 172 participants depending on study designs. Studies varied from retrospective, prospective cohort studies, experimental with the preponderance of the studies being cross-sectional. The majority of studies (n=50, 71.4%) involved RL participants. Two studies had participants drawn from both RL and RU [24, 29].

4.3.7.2 Physiological characteristics and the corresponding tests

Table 4-1 provides an overview of physiological characteristics, corresponding tests used to measure each construct in rugby and the absolute number of studies that used a specific physiological test. This review identified 15 physiological characteristics commonly evaluated among rugby players. These include *speed, repeated-sprint and effort ability, repeated high-intensity exercise performance, prolonged high-intensity intermittent running ability/endurance, anaerobic endurance, maximal aerobic power and speed, agility, lower-body muscular power and strength, upper-body muscular strength and power, upper-body muscular endurance and abdominal endurance*. However, there were no studies evaluating muscle flexibility of the rugby players that met the inclusion criteria.

Table 4-1: An overview of tests used to measure specific physiological characteristics

Physiological construct	Corresponding test(s)	Reference(s)	N
Speed	10m, 20m and 40m sprint test	[30-41]	12
	10m, 20m, 30, and 60m sprint test	[41-48]	8
	10m and 40m sprint test	[7, 10, 16, 27, 49, 61, 77]	7
	10m and 20m sprint test	[5, 18, 55-57, 69]	6
	5m, 10m and 20m sprint test	[19, 29, 75]	3
	10m, 20m and 30m sprint test	[17, 48, 52]	3
	10m and 30m sprint test	[6, 62]	2
	5m, 10m, 20m and 40m sprint test	[53, 59]	2
	10m and 60m sprint test	[66]	1
	10m, 20m, 30m and 40m sprint test	[64]	1
	10m, 30m and 40m sprint test	[76]	1
	10m, 20m, 30m, 40m and 50m sprint test	[8]	1
	5m, 10m and 30m sprint test	[79]	1
	5m and 10m sprint test	[73]	1
	15m and 40m sprint test	[58]	1
	20m sprint test	[63]	1
Repeated-sprint ability	Repeated 20m sprint test	[16, 29, 49-51]	5
	Rugby specific repeated speed (RS^2) test	[17, 52]	2
Repeated-effort ability	Repeated effort ability test	[51]	1
Repeated high intensity exercise performance	Repeated high intensity exercise (RHIE) Back test	[24]	1
	Repeated high intensity exercise (RHIE) RL Forward test	[24]	1
	Repeated high intensity exercise (RHIE) RU Forward test	[24]	1
Prolonged high-intensity intermittent running ability/Endurance	Yo-yo intermittent recovery test (level 1)	[15, 18, 53-56, 59, 60]	8
	Repeated 12s sprint shuttle speed test	[16, 49, 50]	3
	Yo-yo intermittent recovery test (level 2)	[24]	1
	Multistage fitness test	[57]	1
	5 minute run	[58]	1

Maximal aerobic power/uptake	Multistage fitness test	[7, 8, 10, 16, 27, 30-37, 40, 41, 43-46, 48-50, 61-67]	29
	Yo-yo intermittent recovery test (level 1)	[69]	1
	30-15 Intermittent Fitness test (30-15_{IFT})	[68]	1
	1 500m run (Metabolic Fitness Index)	[42]	1
Maximal aerobic speed/Anaerobic speed reserve	30-15 Intermittent Fitness test (30-15_{IFT})	[53, 59]	2
Anaerobic capacity	Triple 120m shuttle (T120S) test	[70]	1
	Wingate 60 (w60) cycle test	[70]	1
	300m shuttle run test	[71]	1
	400m sprint test (Metabolic Fitness Index for Team Sports)	[42]	1
Change of direction speed/Agility	(Agility) 5-0-5 test	[16, 19, 36, 37, 41, 43-49, 53, 65-67, 72]	17
	L-run	[19, 31, 32, 34, 35, 40, 58]	7
	Illinois Agility test	[27, 30, 64]	3
	Modified 5-0-5 test	[19, 73]	2
	Change of direction speed test	[6, 74]	2
	Agility test	[75]	1
	Novel agility test (no specific name given)	[77]	1
Lower body muscular power	Vertical (Sargent) jump test	[15, 16, 30-36, 40, 49, 61, 64, 65, 73]	15
	Countermovement jump test (CMJ)	[18, 38, 39, 41, 43-48, 53, 55-57, 60, 62, 63, 66, 67, 69, 75, 76]	22
	Jump squat test	[13, 75, 77-79]	5
Lower body muscular strength	1 repetition maximum (RM) back squat	[5, 17, 18, 38, 55, 56, 69, 77, 80]	9
	1 RM box squat	[13, 42]	2
	3 RM back squat	[15, 60]	2
	Isometric squat on force plate	[75]	1
Upper body muscular power	2-kg medicine ball chest throw	[41, 43-48, 57, 66]	9
	20-s push-up test	[36]	1
	Overhead medicine ball throw	[73]	1
	Bench throw	[13]	1
	20-s chin up test	[36]	1
	Plyometric Press-up	[60]	

Upper body muscular strength	1RM bench press	[5, 7, 17, 18, 27, 38, 42, 55, 56, 58, 69, 78, 80]	13
	1RM chin up test	[17, 42]	2
	3RM bench press	[15, 60]	2
	Push test	[27]	1
	Prone row	[18]	1
Upper body muscular endurance	60-s push-up test	[36]	1
	60-s chin- up test	[36]	1
	Bench press repetitions-to-fatigue at 60% 1RM	[81]	
	1RM Bench press repetitions-to-fatigue at 60kg	[81]	1
	1RM Bench press repetitions-to-fatigue at 102.5kg	[81]	
	Pull up test	[7]	1
	Body mass bench press with repetition	[15]	1
	30-s plyometric push-up test	[58]	1
Abdominal endurance	60-s sit-up	[58]	1

* The physiological characteristic is written as described in the original article, RU=Rugby Union, RL=Rugby League

The majority of these physiological characteristics had multiple tests for measurement. Overall, the 70 studies included in the review described 63 physiological tests: speed (8), upper-body muscular endurance (8), agility/change of direction speed (7), upper-body muscular power (6), upper-body muscular strength (5), prolonged high-intensity intermittent running ability/endurance (5), lower-body muscular strength (5), anaerobic endurance (4), maximal aerobic power (4), lower-body muscular power (3), repeated high-intensity exercise performance (3), repeated-sprint ability (2), repeated-effort ability (1), maximal aerobic speed (1) and abdominal endurance (1). Appendix K summarises the procedures for administering each physiological test identified.

Speed

Running speed was the most common physiological characteristic evaluated among rugby players. Of the 70 studies, 51 (72.9%) examined the speed characteristics of rugby players. Straight-line sprinting was commonly measured over eight distances of 5m, 10m, 15m, 20m, 30m, 40m, 50m and 60m recorded using dual-beam electronic timing gates (Table 4.1 and Appendix K). Of the 50 studies, 98% of the studies assessed the speed of rugby players over multiple distances. Twelve (24%) studies specifically used multiple linear distances of 10m, 20m and 40m [30-41] and eight (16%) used the 10m, 20m, 30m and 60m sprint tests for the speed evaluation of rugby players [41-48].

Repeated sprint and effort ability

There were seven (10.0%) studies that evaluated repeated-sprint abilities of rugby players. However, only two tests were commonly used in these studies to evaluate the construct. The repeated 20m sprint test was used in five of the seven studies [16, 29, 49-51]. The test involves players performing 10 or 12 maximal effort sprints over a 20m distance with each sprint performed on a 20 or 30second cycle [16, 29, 49-51]. In addition, there were two studies that evaluated the repeated sprint abilities of rugby participants using the rugby-specific repeated speed (RS^2) test [17, 52]. The repeated-effort ability (REA) test was used in one study to investigate the physiological characteristic of repeated-effort ability in rugby players [51]. The protocol comprises of 12×20m sprints and tackles with each sprint commencing every 20seconds and the tackle performed after each 20-m sprint [51].

Repeated high-intensity exercise performance

The ability to perform repeated high-intensity exercises by rugby players was assessed using specifically developed repeated high-intensity exercise (RHIE) tests. Three tests were used in a study by Austin et al [24] and were modified for RU backline players, RU forward players and RL forward players.

Prolonged high-intensity intermittent running ability/endurance

Fourteen (20.0%) studies investigated the measurement of a physiological characteristic termed "prolonged high-intensity intermittent running ability" or endurance [15, 16, 18, 24, 49, 50, 53-60]. Of the 14 included studies, eight used the Yo-Yo intermittent recovery level 1 test (Yo-Yo IRT1) [15, 18, 53-56, 59, 60] and three utilised the repeated-12s sprint shuttle speed test [15, 49, 50]. The Yo-Yo IRT1 involves performing 2×20m runs back and forth at a progressively increasing speed keeping to a series of beeps/audio signals from compact disc [15, 53, 54]. The repeated 12s sprint shuttle speed test involves players performing 8×12s maximal effort shuttles (sprinting forward 20m, turning 180 degrees and sprinting 20m) and each shuttle is performed at 48seconds cycle [16, 49, 50]. In addition, there was only one study that evaluated the construct of "prolonged high-intensity intermittent running ability" using the Yo-Yo intermittent recovery level 2 (Yo-Yo IRT2) test [24].

Maximal aerobic power and speed

Of the 70 studies, 32 (45.7%) studies estimated the maximal aerobic power of rugby players. Of these studies, 29 (90.6%) used the multistage fitness test [7, 8, 10, 16, 27, 30-37, 40, 41, 43-46, 48-50, 61-67]. Other tests used in singular studies to estimate maximal aerobic power included the 30-15 Intermittent Fitness test (30-15_{IFT}) [68], 1 500m run [42] and the Yo-Yo IRT1 [69]. Maximal aerobic speed was evaluated using the 30-15 intermittent fitness test (31-15_{IFT}) [53, 59]. The test involves performing 30s shuttle runs conducted at a pace governed by a pre-recorded beep and interspersed with 15s periods of passive recovery. The test begins at 8km/hr and increased to 0.5km/hr at each successive running shuttle [53].

Anaerobic endurance

Three (4.28%) studies assessed the anaerobic endurance of rugby players. One study compared the results of rugby players on two tests of anaerobic endurance: Triple 120m (T120S) test and the Wingate 60 (w60) cycle test [70]. Other tests used in singular studies included the 300m shuttle run test [71] and the 400m sprint test [42].

Change of direction speed/agility

The change of direction speed/agility of rugby players was commonly measured in a number of studies. It was the third most commonly measured physiological characteristic in the included studies. In total, 33 (47.1%) studies examined the change of direction speed or agility of rugby players. Of these studies, 17 (51.5%) used the 5-0-5 test [16, 19, 36, 37, 41, 43-49, 53, 65-67, 72] and seven (21.2%) used the L-run test [19, 31, 32, 34, 35, 40, 58]. The 5-0-5 test involves players assuming a starting position 10m from timing gates and accelerate as quickly as possible along the 15-m distance, pivot on the 5m line or turn 180 degrees at the 15m mark and return as quickly as possible through the timing gates placed 5m from a designated turning point [16, 19, 36, 37, 49, 53, 72]. On the other hand, the L-run involves three cones placed 5m apart in an ‘L’ shape and players have to run as quickly as possible along the 5m, turn left, run forward 5m, turn 180 degrees and follow the same course to finish [19, 31, 32, 34, 35, 40]. Other tests used in the included studies are the Illinois agility test (n=3) [27, 30, 64], modified 5-0-5 test (n=2) [19, 73] and change of direction speed test (CODS) (n=2) [6, 74].

Lower-body muscular power and strength

Lower-body muscular power was the second most commonly investigated physiological characteristic in rugby participants. Of the 70 studies, 42 (60.0%) studies included in this review examined that construct. Of these studies, 15 (35.7%) used the vertical jump (VJ) test [15, 16, 30-36, 40, 42, 49, 61, 64, 65, 73]. The VJ involves using a Yardstick device or a board and players are instructed to stand with feet flat on the ground, fully extended arms and hands, and mark the standing reach height. After assuming a crouch position, players are requested to spring upward and touch the yardstick device or the board at the highest possible point [15, 16, 30-36, 40, 42, 49, 61, 64, 65, 73]. Twenty-two (52.4%)

studies used the countermovement jump (CMJ) test [18, 38, 39, 41, 43-48, 53, 55-57, 59, 60, 62, 63, 66, 67, 69, 75, 76]. The difference in the two vertical jump tests is that the CMJ involves participants standing with their hands positioned on the hips and usually jump from a jump mat as high as possible [18]. The jump squat (JS) test was used in five studies [13, 75, 77-79].

Of the 70 studies, 14 (20.0%) assessed lower-body muscular strength of rugby players. The most frequently used test was the one-repetition maximum back squat (1-RM BS). The test was used in nine of the fourteen studies [5, 17, 18, 38, 55, 56, 69, 77, 80]. Using an Olympic bar or free weights, players are instructed to back squat until the top of the thigh is parallel with the ground and return to a standing position to record 1-RM [5, 17, 38, 55, 56, 69, 77, 80]. In addition, two studies used the 1-RM box squat [13, 42] and 3-RM back squat [15, 60], respectively.

Upper-body muscular power and strength

Nineteen (27.1%) studies evaluated the upper-body muscular strength of rugby players. Of these studies, 13 (68.4%) used the 1-RM bench press [5, 7, 17, 18, 27, 38, 42, 55, 56, 58, 69, 78, 80]. The 1-RM BP test involves players in supine, feet flat on floor, hips and shoulders in contact with the bench. The players are instructed to lower the bar to touch the chest and push the bars until the elbows are locked out, recording the 1-RM [5, 7, 17, 27, 38, 42, 55, 56, 69, 78, 80]. Two studies used the 1-RM chin-up test [17, 42] and the 3-RM bench press [15, 60]. On the other hand, there were 12 (17.1%) studies that examined that upper-body muscular power for rugby players. The frequently used test in the included studies was the 2-kg medicine ball chest throw [41, 43-48, 57, 66]. Other tests used in singular studies included the 20-s push-up and 20-s chin-up tests [36], overhead medicine ball throw test [73], and bench throw test [13].

Upper-body and abdominal muscular endurance

Of the included studies, upper-body muscular endurance was assessed in five studies only (7.14%). One singular study utilised two tests: 60-s push-up and chin-up tests [36]. Another study used the 1-RM bench press repetitions-to-fatigue test at 60kg, 102.5kg and at 60% of 1-RM [81]. Other tests used in singular studies included the pull-pp test [7] and the body mass bench press with repetition test [15] and the 30-s plyometric push-up test [58]. Abdominal endurance was identified in one study and was assessed using the 60-s sit-up test [58].

4.4 Stage 2: Methods

Stage 1 allowed us to identify tests commonly used for the measurement of physiological characteristics of speed, repeated sprint ability and effort, repeated high-intensity exercise performance, prolonged high-intensity intermittent running ability/endurance, maximal aerobic power and speed, anaerobic endurance, change of direction speed/agility, lower and upper-body muscular strength, power, and abdominal endurance. Briefly, the second stage of the systematic review was conducted to provide evidence on the measurement properties of each identified physiological test from Stage 1. The ultimate aim, however, was to identify one physiological test per physiological construct with the strongest level of evidence on measurement properties on best evidence synthesis.

4.4.1 Literature search, search strategy and eligibility criteria

The electronic databases used for literature search in Stage 1 were used for Stage 2. Initially, we searched specifically for full-text studies with the primary purpose of investigating the measurement properties (reliability, validity and responsiveness) of the previously identified physiological tests in male rugby participants. This was done for the determination of physiological tests validated in the population of interest to the researcher (MC) for his future studies using rugby participants [21, 82]. However, provided that there was no satisfactory information found on the measurement properties for certain physiological tests in rugby studies, it was pre-planned that we would search for the evidence from clinimetric studies on related, intermittent, collision team sports such as Australian Rules football (AFL), American football, Gaelic football and Soccer. But, included studies from related sports had to have a similar description of the procedure of the test as described in rugby-related studies. In cases where there were major adjustments according to the researcher (MC) in the procedure of test between sports such studies were excluded. A search strategy proposed by Terwee et al [83] guided the selection of keywords (see Appendix L). The strategy for searching clinimetric studies in rugby and related sports consisted of a combination of following search themes (i, ii, iii, iv) and (i, ii, iv, v), respectively, connected with the Boolean term AND:

i. Test-specific terms: *Vertical jump test* OR *Yo-Yo intermittent recovery test* OR *repeated 20m sprint test*.

ii. Measurement property-related terms*: Psychometric** OR *measurement** OR *clinimetric**.

iii. Rugby-related terms: *rugby* OR *rugby union* OR *rugby league*.

iv. Target population-related search terms: *adult* OR *adolescent* OR *male*

v. Other team sport-related terms: *Australian Rules football* OR *American football* OR *Soccer*.

4.4.2 Data extraction

The selection process of the identified articles was conducted as described previously in stage 1. Subsequently, data extraction was conducted using two independent people. All the data extracted was put on Microsoft Excel and was given to two other independent assessors for further verification purposes on the accuracy of the data. The following data were extracted: publication details (first author, year of publication), title, purpose of the study, age of the participants, country, sport context, physiological construct evaluated, test(s) used to measure the construct, and the measurement properties assessed (reliability, validity and responsiveness). For the measurement properties, the following data were extracted: type of reliability or validity, interval period for test-retest and inter-rater studies, sample size and the results obtained for each physiological test.

4.4.3 Quality assessment of the clinimetric studies and measurement properties

The Consensus-based Standards for the Selection of health Measurement Instruments (COSMIN) checklist was used to evaluate the methodological quality of the included studies. Briefly, the COSMIN evaluates nine measurement property items *(internal consistency, reliability, measurement error, content validity, construct validity (i.e. structural validity, hypothesis testing, cross-cultural validity), criterion validity and responsiveness)* (Table 4-2). It also provides standardised information for evaluating the quality of each item based on design requirements and statistical methods [84, 85]. The COSMIN scoring system per measurement property is based on a point rating scale (poor to excellent) and the overall rating for the methodological quality of each study is obtained by taking the lowest score [83, 84].

Table 4-2: Quality criteria of rating the results of measurement properties

Measurement property	Definition	(Rating) Quality criteria[a,b]
Reliability		
Internal consistency	The extent to which items in a (sub)scale are intercorrelated, thus measuring the same construct	(+) Factor analyses performed on adequate sample size (7 * # items and >100) AND Cronbach's alpha(s) calculated per dimension AND Cronbach's alpha(s) between 0.70 and 0.95; (?) No factor analysis OR doubtful design or method (-) Cronbach's alpha(s) 0.70 or O0.95, despite adequate design and method. (0) No information found on internal consistency.
Reproducibility		
Agreement	The extent to which the scores on repeated measures are close to each other (absolute measurement error)	(+) MIC < SDC OR MIC outside the LOA OR convincing arguments that agreement is acceptable. (?) Doubtful design or method OR (MIC not defined AND no convincing arguments that agreement is acceptable) (-) MIC > SDC OR MIC equals or inside LOA, despite adequate design and method; (0) No information found on agreement.
Reliability	The extent to which patients can be distinguished from each other, despite measurement errors (relative measurement error)	(+) ICC > 0.70 OR k > 0.70 (?) Doubtful design or method (e.g., time interval not mentioned) (-) ICC or weighted Kappa ≤0.70, despite adequate design and method (0) No information on reliability found
Validity		
Content Validity	The extent to which the domain of interest is comprehensively sampled by the items in the questionnaire	(+) A clear description is provided of the measurement aim, the target population, the concepts that are being measured, and the item selection AND target population and (investigators OR experts) were involved in item selection; (?) A clear description of above-mentioned aspects is lacking OR only target population involved OR doubtful design or method; (-) No target population involvement; (0) No information found on target population involvement.
Construct validity	The extent to which scores on a particular questionnaire relate to other measures in a manner that is consistent with theoretically derived hypotheses concerning the concepts that are being	(+) Specific hypotheses were formulated AND at least 75% of the results are in accordance with these hypotheses; (?)Doubtful design or method (e.g., no hypotheses); (-) Less than 75% of hypotheses were confirmed, despite adequate design and methods; (0) No information found on construct validity.

	measured	
Criterion validity (predictive or concurrent	The extent to which scores on a particular questionnaire relate to a gold standard	[C](+) correlation with standard ≥ 0.70 OR no statistically significant differences between the two tests found OR sensitivity and specificity ≥ 0.70 OR convincing arguments that gold standard is "gold" AND correlation with gold standard >0.70; (?)No convincing arguments that gold standard is "gold" OR doubtful design or method; (-) Correlation with standard < 0.70 or AUC < 0.70 OR statistically significant differences between outcome measures and gold standard OR sensitivity or specificity < 0.70
Responsiveness	The ability of a questionnaire to detect clinically important changes over time	(+) SDC or SDC < MIC OR MIC outside the LOA OR RR O 1.96 OR AUC > 0.70; (?) Doubtful design or method; (-) SDC or SDC > MIC OR MIC equals or inside LOA OR RR < 1.96 OR AUC < 0.70, despite adequate design and methods. (0)No information found on responsiveness.
Floor and ceiling effects	The number of respondents who achieved the lowest or highest possible score	(+) ≤ 15% of the respondents achieved the highest or lowest possible score (?) Doubtful design or method (-) > 15% achieved the highest and lowest possible score despite adequate designs and methods (0) No information found on interpretation
Interpretability	The degree to which one can assign qualitative meaning to quantitative scores	(+) Mean and SD scores presented of at least four relevant subgroups of patients and MIC defined; (?) Doubtful design or method OR less than four subgroups OR no MIC defined; (0) No information found on interpretation.

MIC=minimal important change; SDC=smallest detectable change; LOA=limits of agreement; ICC=Intraclass correlation; SD=standard deviation. a (+) positive rating; (?) indeterminate rating; (-) negative rating; (0) no information available. [b]Doubtful design or method= lacking of a clear description of the design or methods of the study, or any important methodological weakness in the design or execution of the study.

Two reviewers with prior COSMIN experience evaluated the methodological quality of each study included in Stage 2. It was pre-planned that disagreements were resolved by discussion with the third person until a consensus was reached. In addition to the methodological quality assessment with the COSMIN, the quality criteria for rating of measurement properties checklist as given by Terwee et al [86] was used to rate each measurement property in the included articles as *"positive", "negative" or "questionable"* depending on the results of the property reported (Table 4.2). Studies with "poor" methodological qualities were not analysed for the quality of the results on the measurement properties.

4.4.4 Best evidence synthesis: levels of evidence

To help synthesise results from numerous studies on the same physiological construct, the "best evidence synthesis" approach was performed by the primary author (MC). The best evidence synthesis rating was determined based on the number of studies that have investigated the measurement property, the overall COSMIN score, and the rating and consistency of the measurement property result (positive, indeterminate, and negative) [87]. The possible levels of evidence are *"strong"* (when consistent findings in multiple studies of good methodological quality were found or in one excellent methodological quality study), *"moderate"* (when consistent findings in multiple studies of fair methodological quality were found or in one study of good methodological study), *"limited"* (if only one study of fair methodological quality was found), *"conflicting"* (conflicting findings) and *"unknown"* (if only studies of poor methodological quality were found or no studies) [87].

4.4.5 Results: Stage 2

4.4.5.1 Characteristics of included studies

Figure 4-2 shows a flow chart for the selection of the studies. Of 824 studies identified from the electronic databases, 20 met the inclusion criteria.

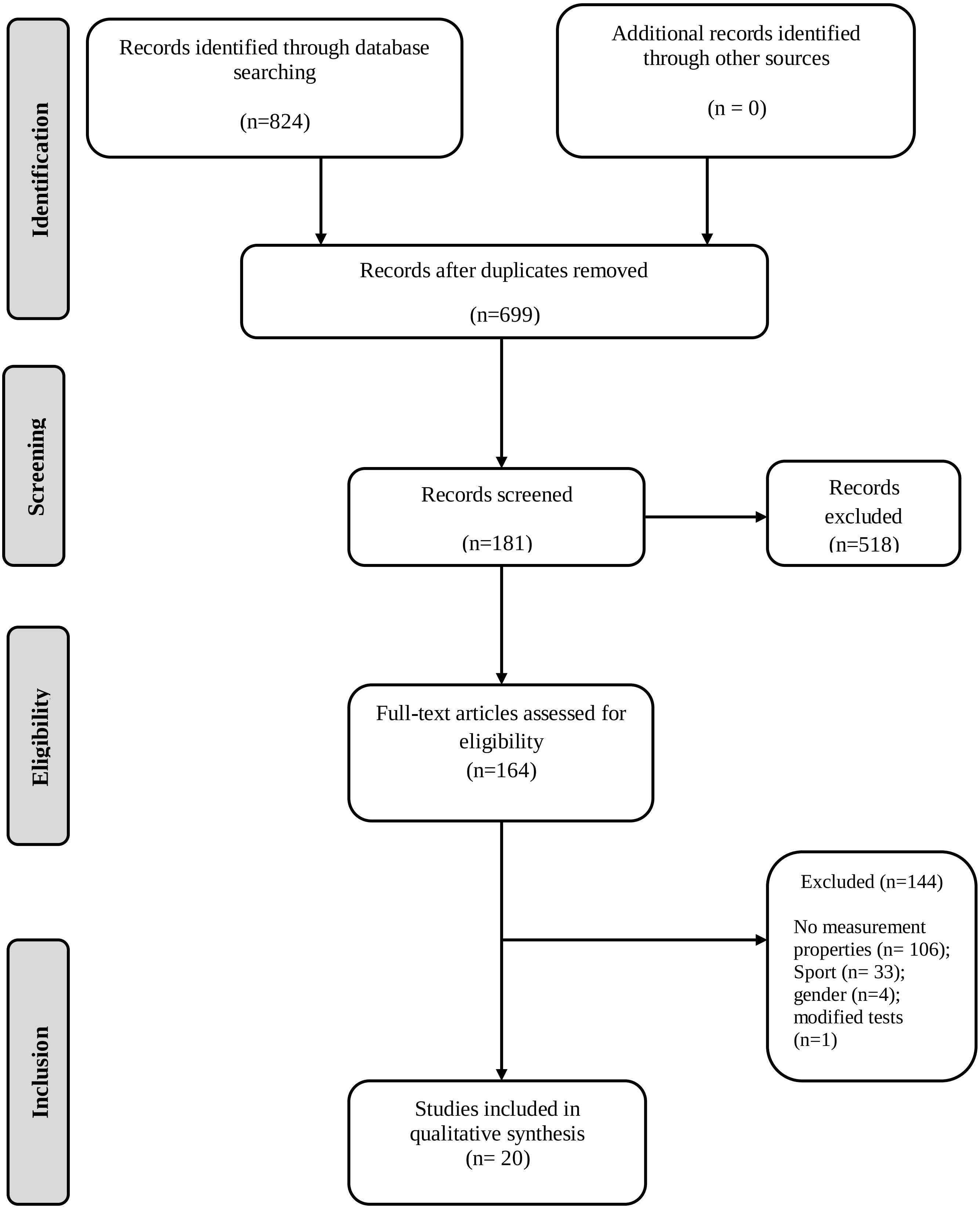

Figure 4-2: Flow chart for the search and selection of Stage 2 articles

The majority of the studies did not meet the inclusion criteria because they did not report on measurement properties. The general characteristics of the included studies and a summary of the measurement properties evaluated in each study are summarised in Appendix M. The studies were conducted in Australia (n=9), Denmark, Brazil, Belgium (n=2), Norway, Ireland, Iran, Italy and Croatia (n=1). The age of the participants in the included studies ranged from 12 to 36 years.

Out of the 63 tests identified in stage 1, 20 studies described the measurement properties of only 21 tests. The tests were the 5-m, 10-m, 20-m and 30-m speed tests (speed), 20-m repeated-sprint test (repeated sprinting ability), repeated-effort test (repeated effort ability), three repeated high-intensity exercise tests (repeated high-intensity exercise performance), Yo-Yo IRT1 and 2 (prolonged high-intensity running ability), T120s (anaerobic endurance), 5-0-5 test (agility), modified 5-0-5 test (agility), L-run (agility), change of direction speed test (agility), sergeant jump test (lower-body muscular power), and three bench press repetition-to-fatigue tests (upper-body strength-endurance).

Of the 21 tests, 18 were studied for their measurement properties in rugby. The Yo-Yo intermittent recovery level 1 and 2 and the sergeant jump tests had their measurement properties derived from other related sports (soccer and Australian Rules football). Other than the tests mentioned above, there was no evidence on the measurement properties either in rugby or related sports for all the other tests identified in stage 1. However, for the 21 tests identified in stage 2, none of the tests had all the measurement properties investigated. But, the majority of the studies (n=7) investigated the reliability and validity of one or more physiological tests [6, 19, 74, 88-91].

4.4.5.2 Measurement properties and methodological quality assessments

Table 4-3 and Table 4-4 provide an overview of the measurement properties for the identified physiological tests and the COSMIN rating of methodological quality for the studies per measurement property.

Table 4-3: Reliability, measurement error and methodological quality scores

Test	Reliability (Intra-rater, inter-rater, test-retest) and measurement error			COSMIN
	Design (interval period)	***n***	**Results**	**Score**
RHIE Backs test[24]	Test-retest (2 days)	12	Total sprint time, ICC=0.82 (CV=0.1-3.2%); Percentage decrement, ICC=0.78 (CV=4.2-49.5%)	Poor
RHIE RL Forward test[24]	Test-retest (2 days)	12	Total sprint time, ICC=0.97 (CV=0.1-4.9%); Percentage decrement, ICC=0.86 (CV=1.4-48.2%)	Poor
RHIE RU Forward test[24]	Test-retest (2 days)	12	Total sprint time, ICC=0.94 (CV=0.1-5.1%); Percentage decrement, ICC=0.88 (CV=0.6-35.8%)	Poor
5-m sprint[19]	Test-retest (2 days)	42	Fastest time, ICC=0.84 (% TE=3.2)	Fair
10-m sprint[19]	Test-retest (2 days)	42	Fastest time, ICC=0.87 (%TE=1.9)	Fair
10-m sprint with foot start[99]	Test-retest (7 days)	15	ICC=0.86 (TE%=0.9)	Poor
10-m sprint with standing start[99]	Test-retest (7 days)	15	ICC=0.92 (TE%=0.88)	
10-m sprint with thumb start	Test-retest (7 days)	15	ICC=0.92 (TE%=1.00)	
10-m sprint[6]	Test-retest (3 days)	11	Average sprint time, ICC=0.88 (SEM=0.08)	Poor
20-m sprint [19]	Test-retest (2 days)	42	Fastest time, ICC=0.96 (% TE=1.3)	Fair
30-m sprint[6]	Test-retest (3 days)	11	Average sprint time, ICC=0.97 (SEM=0.06)	Poor
5-0-5 test[19]	Test-retest (2 days)	42	Fastest time, ICC=0.90 (%TE=1.9)	Fair
Modified 5-0-5 test[19]	Test-retest (2 days)	42	Fastest time, ICC=0.92 (%TE=2.5)	Fair
L-run test[19]	Test-retest (2 days)	42	Fastest time, ICC=0.95 (%TE=2.8)	Fair
CODS test[6]	Test-retest (3 days)	11	Average time, ICC=0.87 (SEM=0.06)	Poor
CODS test[74]	Test-retest (7 days)	15	Average time, ICC=0.87 (SEM=0.01)	Poor
T120S test[70]	Test-retest (4 days)	12	Total time taken, r=0.74 (p=0.006)	Poor
20m RSA test[51]	Test-retest (7 days)	12	Total sprint time, ICC=0.96 (%TE=1.5) Decrement (%), ICC=0.91 (%TE=22.5) Average heart rate, ICC=0.56 (%TE=3.5) Peak heart rate, ICC=0.88 (%TE=1.4)	Poor

			Rating of perceived exertion, ICC=0.78 (%TE=5.5)	
REA test[51]	Test-retest (7 days)	12	Total time, ICC=0.82 (%TE=2.3) Decrement (%), ICC=0.91 (%TE=6.7 Average heart rate, ICC=0.96 (%TE=0.9) Peak heart rate, ICC=0.88 (%TE=1.5) Rating of perceived exertion, ICC=0.59 (%TE=3.3)	Poor
30-15$_{IFT}$ test[68]	Test-retest (9 days)	55	Maximal intermittent running velocity (V_{IFT}), ICC=0.89 (CV%=1.9); SWC=0.21	Good
		13	Heart rate, ICC=0.96 (CV%=0.6); SWC=1 beats per minute	Poor
Yo-Yo IR1[88]	Test-retest (8 days)	35	Under 13: Total distance, ICC=0.82 (CV%=17.3); LoA= 0.98 ×/÷ 1.27, range=0.77-1.24	Poor
		32	Under 15: Total distance, ICC=0.85 (CV%=16.7); LoA= 0.89 ×/÷1.30, range=0.68-1.16	
		11	Under 17: Total distance, ICC=0.94 (CV%=7.9); LoA= 0.94 ×/÷ 1.15, range=0.82-1.08	
Yo-Yo IR1[89]	Test-retest (within 1 week)	13	Total distance, r=0.98 (CV%=4.9)	Poor
Yo-Yo IR1[94]	Test-retest (7 days)	24	Total distance, ICC=0.78 (CV=7.3%)	Poor
Yo-Yo IR2[94]	Test-retest (7 days)	24	Total distance, ICC=0.93 (CV=7.1%)	Poor
Yo-Yo IR1[96]	Test-retest (3 measurements within 1 week intervals)	22	Under 15: Total distance, ICC=0.92 (CV%=6.8-7.5); 95% ratio LoA (test 1 vs. test 2) =1.17 */÷ 1.24; 95% ratio LoA (test 2 vs. 3) = 0.96 */÷ 1.23; 95% ratio limit (test 1 vs. 3) = 1.13 */÷ 1.28.	Poor
		10	Under 17: Total distance, ICC= 0.95 (CV%=3.1-5.4); 95% ratio LOA (test 1 vs. test 2) = 1.09 */÷ 1.13; 95% ratio LoA (test 2 vs. 3) = 0.97 */÷ 1.09; 95% ratio LoA (test 1 vs. 3) = 1.06 */÷ 1.15.	
		4	Under 19: Total distance, ICC=0.87 (CV%=3.0-6.9); 95% ratio LoA (test 1 vs. test 2) = 1.02 */÷ 1.11; 95% ratio LoA (test 2 vs. 3) = 0.88 */÷ 1.12; 95% ratio LoA (test 1 vs 3) = 0.90 */÷ 1.22.	
Yo-Yo IR2[98]	Test-retest (2 days)	29	Total distance, CV%=9.6%.	Poor
Yo-Yo IR2[91]	Test-retest (7 days)	18	Total distance, ICC=0.38 (CV%=11)	Poor
Vertical (Sergeant) jump test[90]	Intra-rater (testing sessions	45	ICC=0.99 (95% CI=0.99-1.00)	Fair

	separated by 2hrs)			
	Inter-rater	45	ICC=1.00 (95% CI=0.99-1.00)	Fair

Sign diff=significant differences; b/w=between; CV%= Coefficient of Variation expressed as a percentage; CI=confidence interval; ICC=Intraclass correlation coefficient; r= Pearson correlation coefficient; * highest effect size calculated between groups; SWC=smallest worthwhile change; n=sample size; IFT=Intermittent fitness test; TE%=Percent typical error of measurement; CODS=Change of direction speed; T120S=Tripple-120meter shuttle test; r=Pearson's product moment correlations; RSA=repeated sprint ability; REA=repeated effort ability; SWC=smallest worthwhile change; 95% ratio LoA= limits of agreement; Yo-Yo IR1 and 2= Yo-Yo intermittent recovery tests 1 and 2.

Table 4-4: Validity, responsiveness and methodological quality scores

Test	Validity			COSMIN	Responsiveness			COSMIN
	Type	*n*	Results	Score	Design	*n*	Results	Score
BP RTF 60[81]	Hypothesis testing (Known group validity)	38	Sign diff b/w groups NRL (36.1±7.2) vs. SRL (28.0±5.6)	Fair	-	-	-	-
BP RTF 102.5[81]	Hypothesis testing (Known group validity)	38	Sign diff b/w groups NRL (12.5±4.3) vs. SRL (5.9±3.9)	Fair	-	-	-	-
BP RTF 60% 1RM[81]	Hypothesis testing (Known group validity)	26	No sign diff b/w NRL and SRL players	Poor	-	-	-	-
5m sprint test[19]	Hypothesis testing (Known group validity)	42	Sign diff b/w groups (First grade RL players vs. Second grade RL players) Effect Size=0.68	Fair	-	-	-	-
10m sprint test[19]	Hypothesis testing (Known group validity)	42	Sign diff b/w groups (First grade RL players vs. second grade RL players) Effect size=0.85	Fair	-	-	-	-
10m sprint test[6]	Hypothesis testing (Known group validity)	28	Sign diff b/w (Club RU players vs. Academy RU players) Effect size=2.86	Poor	-	-	-	-
30m sprint test[6]	Hypothesis testing (Known group validity)	28	Sign diff b/w (club RU players vs. Academy RU players) Effect size=1.61	Poor	-	-	-	-
5-0-5 test[19]	Hypothesis testing (Known group validity)	42	No sign diff b/w between groups Effect size=0.28	Fair	-	-	-	-
Modified 5-0-5 test[19]	Hypothesis testing (Known group	42	No sign diff b/w groups Effect size=0.32	Fair	-	-	-	-

	validity)							
L-run[19]	Hypothesis testing (Known group validity)	42	No sign diff b/w groups Effect size=0.28	Fair	-	-	-	-
CODS test[6]	Hypothesis testing (Known group validity)	28	Sign diff b/w groups. Effect size=2.23	Poor	-	-	-	-
CODS test[74]	Hypothesis testing (Known group validity)	30	No sign diff b/w groups (Low performance group, n=15 vs. High performance group, n=15)	Poor	-	-	-	-
T120S test[70]	Criterion validity	12	Sign corr in maximum heart rate b/w the 2 trials of T120S and W60 cycle test (r=0.63 and 0.71). No sign corr b/w 2 trials of T120S and W60 cycle test for post 3minutes lactate (r=0.11 and 0.10).	Poor	-	-	-	-
Yo-Yo IR2[97]	Hypothesis testing (Known group validity)	51	Sign diff b/w elite vs. sub-elite soccer players.	Poor	-	-	-	-
	Hypothesis testing (convergent validity)	12 39	Sign corr b/w Yo-Yo IR2 and Yo-Yo IR1 (r=0.74, p<0.01) for the elite players. Sign corr b/w Yo-Yo IR2 and Yo-Yo IR1 (r=0.76, p< 0.01) for sub-elite players.	Poor				
	Hypothesis testing (convergent validity)	12 39	Sign corr b/w Yo-Yo IR2 and 35m repeated sprint ability test (r=-0.74, p< 0.01) for elite players. Moderate corr observed for sub-elite (r=-0.34, p< 0.05)	Poor				
	Criterion validity	13 12	Moderate corr for sub-elite players b/w Yo-Yo IR2 and treadmill test (r= 0.48, p< 0.01). No significant corr for the elite players	Poor				

			(r=0.59, p< 0.10)					
Yo-Yo IR1[97]	Hypothesis testing (Known group validity)	51	Sign diff b/w elite (n=12) vs. sub-elite (n=39) soccer players	Poor	-	-	-	-
	Hypothesis testing (convergent validity)	12	Very large corr b/w Yo-Yo IR1 and 35m repeated sprint time (r=-0.80, p< 0.01) for elite players (n=12).	Poor				
		39	Large corr b/w Yo-Yo IR1 and 35m repeated sprint time (r=-0.51, p< 0.05) for sub-elite players (n=39)					
	Criterion validity	12	Very large corr. b/w Yo-Yo IR1 and VO_{2MAX} for elite players (r=0.76, p< 0.01).	Poor				
		39	Very large corr b/w Yo-Yo IR1 and VO_{2MAX} for sub-elite players (r=0.73, p< 0.01).					
Yo-Yo IRT1[92]	Hypotheses testing (Known group validity)	60	Sign diff b/w groups (P< 0.001). *ES=3.78 elite Australian rules football (n=20) vs. healthy group (n=20).	Poor	-	-	-	-
Yo-Yo IRT1[88]	Hypotheses testing (Known group validity)	208	Sign diff b/w groups (p<0.001) ES=0.94 (90% CI=0.46-1.43) b/w U15 Elite vs. Sub-elite	Poor	-	-	-	-
Yo-Yo IRT1[89]	Hypotheses testing (Convergent validity)	22	Sign corr b/w Yo-Yo test performances and fitness performances during soccer match assessed using time motion analysis (r=0.53-0.71, p< 0.05)	Poor	Repeated measures, 4 testing sessions [pre-preparation, mid preparation, start season, end season]	10	Sign diff in Yo-yo mean distance covered between preseason measures and seasonal measures (p< 0.05) Sign diff in heart rate measures b/w preseason and seasonal measures (p< 0.05)	Poor
	Criterion validity	17	Sign corr b/w Yo-Yo test performances and time to fatigue (r=0.79, p< 0.05) and maximal oxygen uptake (r=0.71, p< 0.05)					

Yo-Yo IRT1[93]	Hypotheses testing (Known group validity)	106	Sign group differences in Yo-Yo IRT1 among age categories (F=25.3; p< 0.001). *ES= 4.17 (U 13 vs. U 19) p< 0.01	Poor	-	-	-	-
Yo-Yo IRT1[94]	Hypotheses testing (Convergent validity)	24	Sign corr b/w Yo-Yo IRT1 and Yo-Yo IRT2 (r=0.56-0.84)	-	Repeated measures [(3 testing sessions of Yo-yo IRT1 before 11 wks. of training + matches and 2 testing sessions post training + matches]	24	ES= 0.9 (90%CI=0.66-1.18); SWC=3.7%; MDC=20.2%; % changes after training=14.5%; Probability of substantial changes btwn pre-and post-measures=99.9%	Poor
Yo-Yo IRT2[94]	Hypotheses testing (Convergent validity)	24	Sign corr b/w Yo-Yo IRT1 and Yo-Yo IRT2 (r=0.56-0.84).	poor	Repeated measures [(3 testing sessions of Yo-yo IRT2 before 11 wks. of training + matches and 2 testing sessions post training + matches]	24	ES= 0.4 (90%CI=0.17-0.69); SWC=4.8%; MDC=19.5%;	
Yo-Yo IR1[95]	Hypotheses testing (Convergent validity)	14	Large corr b/n Yo-Yo IRT1 and 30-15 IFT (r=0.75, 90%CI=0.57-0.86)	Poor	Pre and post measures interspaced by an 8-week training intervention	14	Within-test % changes = +35% (90% CI=24-45) for Yo-yo IRT1 vs. +7% (90% CI=4-10) for 30-15 IFT ES for the changes (standardised differences): Yo-yo IRT1=1.2 vs. 1.1 for 30-15 IFT	Poor
Yo-Yo IRT2[98]	Criterion validity	13	A sign corr b/w Yo-Yo IR2 and time to fatigue in the incremental running test (r=0.74, p<0.05)	Poor				

Yo-Yo IRT2[91]	Hypotheses testing (Concurrent validity)	18	High positive corr found b/w Yo-Yo IRT2 and PRT >85% MHR during the match (r=0.71, p=0.001)	Poor	-	-	-	
Vertical (Sargent) jump test[90]	Criterion validity	45	ICC=0.99 (95% CI=0.97-1.00) p=0.001	Fair	-		-	-

PRT=performance of time of remaining above 85% MHR in the game; Yo-Yo IR1 and 2= Yo-Yo intermittent recovery test level 1 and 2; T120S=Triple 120m shuttle run test, CODS=Change of direction speed test; ES=effect size, SWC=smallest worthwhile change; MDC=minimal detectable change; 30-15 IFT=30-15 Intermittent fitness test; BP RTF= bench press repetitions to fatigue test; corr=correlation; CI=confidence interval; b/w=between; sign=significant

Table 4-5 shows rating of the quality of the results on the measurement properties based on the quality rating criteria of measurement properties checklist given by Terwee et al [86]. The results on the measurement properties for the physiological tests derived from studies of "poor" methodological quality were excluded from the rating.

Table 4-5: Overall quality scores by study and rating of measurement properties

Test	Reliability			Construct validity		Criterion	Responsiveness	Interpretability
	Intra	Inter	Test-retest	Known group	Convergent/ Concurrent			
BP RTF 60[81]	0	0	0	+	0	0	0	0
BP RTF 102.5[81]	0	0	0	+	0	0	0	0
30-15_{IFT}[68]	0	0	+	0	0	0	0	0
5-m sprint test[19]	0	0	+	+	0	0	0	0
10-m sprint test[19]	0	0	+	+	0	0	0	0
20-m sprint test[19]	0	0	+	+	0	0	0	0
5-0-5 test[19]	0	0	+	-	0	0	0	0
Modified 5-0-5 test[19]	0	0	+	-	0	0	0	0
L-run test[19]	0	0	+	-	0	0	0	0
Sargent (vertical) jump test[90]	+	+	0	0	0	?	0	0

?= doubtful design or method; 0= no information; +=positive rating; -= negative rating; criterion=criterion validity

Yo-Yo intermittent recovery Level 1 (Yo-Yo IR1) test

Of the 20 studies included in the review, seven investigated at least one measurement property of the Yo-Yo IR1 test (Appendix M). Validity was the most commonly studied measurement property with six studies evaluating at least one type of validity [88, 89, 92-95]. There was evidence on known-group validity [88, 92, 93], convergent [89, 94, 95] and criterion validity [89] of the Yo-Yo IR1 test. However, all the six studies were rated "poor" on methodological quality mainly because of the inadequate sample sizes used in the validity analysis. Reliability was the second most commonly studied measurement property with four studies evaluating test-rest reliability (Appendix M) [88, 89, 94, 96]. The test-retest intervals ranged from within one week to eight days [88, 89, 94, 96]. On methodological quality, all the studies investigating the reliability of the Yo-Yo IR1 were rated "poor". In all these studies, the sample size had the lowest score and therefore determined the total score for the study. Another measurement property investigated for the Yo-Yo IR1 was responsiveness. However, responsiveness of the Yo-Yo IR1 test was reported in two studies of "poor" methodological quality [94, 95].

Yo-Yo intermittent recovery Level 2 (Yo-Yo IR2) test

Of the 20 studies included in the review, four studies provided evidence on at least one measurement property of the Yo-Yo IR2 test (Appendix M) [91, 94, 97, 98]. Validity and reliability were the most commonly studied measurement properties of the test [91, 94, 97, 98]. Three studies evaluated the test-retest reliability of the Yo-Yo IR2 with a seven day interval between the assessments [91, 94, 98]. However, all the three studies were rated "poor" on methodological quality mainly because of small sample sizes used for the reliability analysis. On the other hand, there were four studies that investigated the validity of the Yo-Yo IR2 test (Appendix M) [91, 94, 97, 98]. Two studies provided evidence on convergent [94, 97] and criterion validity of the Yo-Yo IR2 test [97, 98]. In addition, singular studies investigated the known-group validity [97] and concurrent validity of the test [91]. All the studies were, however, rated "poor" on methodological quality. Responsiveness of the Yo-Yo IR2 test was examined in one study of "poor" methodological quality [94].

5m sprint test

Only one "fair" study investigated the measurement properties (reliability and validity) of the 5-m sprint test (Appendix M) [19]. The 5-m sprint test was found to have positive rating [i.e. intraclass correlation coefficient (ICC)>0.70] for the test-retest reliability (Appendix M and Table 4.5) [19]. The same study provided evidence on the construct validity of the test (Table 4.4). A positive rating for the known-group validity was found for the 5-m sprint test as specific hypotheses were formulated and at least 75% of the results were in accordance with these hypotheses (Table 4.5). There was no evidence on the responsiveness found for the test.

10m sprint test

Three different studies investigated the measurement properties of the 10-m sprint test (Appendix M) [6, 19, 55]. Reliability was the most commonly studied measurement property. All the three studies had test-retest reliability evidence for the 10-m sprint test, with an interval of two to seven days between the assessments [6, 19, 99]. However, two of the studies were rated "poor" on methodological quality [6, 99]. In one "fair" study, a positive rating for the test-retest reliability (ICC=0.87) of the 10-m sprint test was found [19]. Validity of the 10m sprint test was assessed in two studies [6, 19]. The most common type of validity studied was construct validity (known-group validity). One study was rated as "poor" on methodological quality [6]. In that study, a positive rating of construct validity was found for the 10m sprint test. There was no evidence found on the responsiveness of the test.

20m sprint test

Only one "fair" study investigated the measurement properties (reliability and validity) of the 20-m sprint test (Appendix M) [19]. The 20-m sprint test was found to have positive rating for the test-retest reliability (Table 4.3 and Table 4.5) [19]. The same study provided evidence on the construct validity of the test (Table 4.4). A positive rating for the known-group validity was found for the 20-m sprint test as specific hypotheses were formulated and at least 75% of the results were in accordance with these hypotheses (Table 4.5). There was no evidence on the responsiveness for the test.

30m sprint test

Test-retest reliability evidence of the 30-m sprint test was provided by one study rated "poor" on methodological quality [6]. The study used a sample size of 11 participants to establish the reliability of the test with three days between the test-retest assessments. In the same study, the 30-m sprint test was also assessed for its known-group validity [6]. However, the study was also rated "poor" on quality for the construct validity. There was no evidence found on the responsiveness of the test.

Repeated-sprint ability (RSA) test

One study assessed the test-retest reliability of repeated sprint ability test with assessments being conducted after seven days (Appendix M and Table 4.3) [51]. The study was rated of "poor" methodological quality mainly because of small sample size used in the reliability analysis. There was no evidence on validity or responsiveness found for the test.

Repeated-effort ability (REA) test

One study assessed the test-retest reliability of repeated-effort ability test with assessments being conducted after seven days [51]. The study was rated of "poor" methodological quality mainly because of small sample size used in the reliability analysis. There was no evidence on validity found for the test.

Repeated high-intensity exercise (RHIE) tests

One study evaluated the test-retest reliability of three different repeated high-intensity exercise tests, namely, the repeated high-intensity exercise backs test, repeated high-intensity exercise rugby union forward test, and the repeated high-intensity exercise rugby league forward test [24]. The quality of the study was, however, rated "poor" mainly because of the small sample size per reliability analysis utilised for each test. There was no information on the validity or responsiveness of any of these tests in the literature.

30-15 intermittent fitness test (30-15 $_{IFT}$)

One study assessed the test-retest reliability of the 30-15 intermittent fitness test with nine days separating the two assessments [68]. For the measure of reliability for the primary outcome of maximal intermittent running velocity (V_{IFT}), the study was rated as of "good" methodological quality. A positive rating (ICC=0.89) for the test-retest reliability was reported for the test. Validity of the test was assessed in one study (Appendix M and Table 4.4) [95]. The study was, however, rated "poor" on quality for the convergent validity of the 30-15 intermittent fitness test [95].

Triple 120-meter shuttle test (T120S)

One study examined the test-retest reliability of the Triple 120m shuttle test for anaerobic endurance using a four day interval between assessments [70]. On the other hand, the same study evaluated the criterion validity of the test against the Wingate 60sec (W60) cycle test. The study used a small sample size of 12 rugby league players both for the reliability and the validity study and was rated “poor” on methodological quality. No information was found on the responsiveness of the test.

5-0-5 test

One study examined both test-retest reliability (over two days) and the construct validity of the 5-0-5 test [19]. The study was rated “fair” on methodological quality and a positive rating (ICC=0.90) was reported for the test-retest reliability. For the construct validity, a negative rating was found for the 505 test as the results of the test showed an unexpected marginal effect size (ES=0.28) because there were no significant difference between groups on the performance of the test. No information on responsiveness was found for the test.

Modified 5-0-5 test

Reliability of the modified 5-0-5 test was investigated in one study [19]. The study was “fair” on methodological quality because of the large sample size. A positive rating (ICC=0.92) on the test-retest reliability was found for the test. The same study investigated the construct validity of the test. The study had “fair” methodological quality on validity. A negative rating of construct validity (known-group validity) was found for the modified 5-0-5 test as there was no significant difference between groups (ES=0.32). Therefore, less than 75% of the results were in accordance with the hypotheses. No information was found for the responsiveness of the test.

L-run test

One study examined both the test-retest reliability (over two days) and the construct validity of the L-run [19]. The study was rated “fair” on methodological quality and a positive rating (ICC=0.95) was reported for the test-retest reliability. For the construct validity, a negative rating was found for the L-run test as the results of the test showed an unexpected marginal effect size (ES=0.28). There was no information found on responsiveness of the test.

Change of direction speed test

Two studies reported on the reliability of the change of direction speed test [6, 74]. The test-retest interval ranged between three to seven days. The same studies provided evidence on the construct validity (known-group validity) of the test [6, 74]. However, the two studies were rated "poor" on methodological quality for both reliability and validity. There was no information found on responsiveness of the test.

Sargent (vertical) jump test

For the Sargent Jump test, there was only one study which was found evaluating inter and intra-rater reliability of the test [90]. Intra-rater reliability was assessed with testing sessions separated by two hours whilst inter-rater reliability assessments were separated by two days. The study was rated "fair" on methodological quality. A positive rating for intra-reliability (ICC=0.99) and inter-rater reliability (ICC=1.00) was reported for the test. The same study evaluated the validity of the Sargent Jump test and showed positive criterion validity against the jump platform (JP) test using 45 soccer participants. The study was rated "fair" quality for criterion validity. There was no information found on responsiveness of the test.

Bench press repetitions-to-fatigue tests

One study examined the construct validity of three different upper-body strength-endurance tests, namely, bench press repetitions-to-fatigue at 60% of one-repetition maximum test (BP RTF 60% 1RM), bench press repetitions-to-fatigue at 60kg (BP RTF 60) and bench press repetitions-to-fatigue at 102.5 kg (BP RTF 102.5) [81]. For the BP RTF 60 and 102.5, the study was rated "fair" on methodological quality because of the adequate sample size (n=38). A positive rating of construct validity was found for the two tests. However, for the construct validity of the BP RTF 60% 1-RM test, the study was rated "poor". There was no information on the reliability or responsiveness of the three tests in measuring upper body strength-endurance.

4.4.5.3 Best evidence synthesis: Level of evidence

A summary of best evidence synthesis are presented in Table 4-6. The synthesis was derived from information on the rating of the methodological qualities of the studies and results on the measurement properties of the tests. Only studies with "fair" to "good" methodological quality were used to determine the level of evidence per test for each studied measurement property. Best evidence synthesis showed moderate evidence to support the test-retest reliability of the 30-15_{IFT} test. Limited evidence was found to support the test-retest reliability and the known-group validity of the 5-m sprint test, 10-m speed test, 20-m speed test, 5-0-5 test, modified 5-0-5 test and the L-run tests. There is also limited level of evidence for inter/intra-rater reliability and criterion validity of the Sargent (vertical) jump test. Furthermore, there was limited evidence on the known group validity of the upper-body strength endurance tests of bench-press repetitions-to-fatigue at 60 and 102.5kgs. There is unknown evidence available on the measurement properties of all the other tests identified in stage 1.

Table 4-6: Best level synthesis for the physiological tests

Test	Reliability			Hypothesis testing		Criterion	Responsiveness
	Inter	Intra	Test-retest	Known group	Convergent		
5m sprint test[19]	0	0	+	+	0	0	0
10m sprint test[19]	0	0	+	+	0	0	0
20m sprint test[19]	0	0	+	+	0	0	0
5-0-5 test[19]	0	0	+	0	0	0	0
Modified 5-0-5[19]	0	0	+	0	0	0	0
L-run[19]	0	0	+	0	0	0	0
Sargent jump test[90]	+	+	0	0	0	+	0
BP RTF 60[81]	0	0	0	+	0	0	0
BP RTF 102.5[81]	0	0	0	+	0	0	0
30-15_{IFT}[68]	0	0	++	0	0	0	0

+/-= limited evidence (One study of fair methodological quality); ++/-- moderate evidence (consistent findings in multiple studies of fair methodological quality OR in one study of good methodological quality; 0= no evidence or information available. All the other tests had unknown level of evidence on measurement properties because of poor methodological quality.

4.5 Discussion

The aim of the present systematic review was two-fold. Firstly, we systematically reviewed 70 studies in Stage 1 to identify physiological characteristics evaluated in rugby and the corresponding tests used to measure each construct. Thereafter, 20 studies were systematically reviewed in Stage 2 to provide an overview on the measurement properties of the physiological tests identified in the studies. Most of the included studies from stage 1 were from Australia, United Kingdom, New Zealand, and South Africa. This probably reflects the popularity of the sport of rugby in these respective countries. The fact that there were an almost equal number of adult and adolescent rugby studies indicates that rugby is extensively studied in junior and senior players. It is also possible to speculate that the sport is equally popular among junior and senior players.

One most important finding that emerged from stage 1 was that there are a number of physiological characteristics that are commonly investigated among rugby players. Fifteen physiological characteristics were identified. This extensiveness probably confirms wide interest researchers have in physiological characteristics. The interest could be linked with suggestions that success in rugby is highly dependent on physiological characteristics [75]. With increased professionalism and competition, there has been extensive investment in research towards establishing physical qualities important for successful performance in professional rugby. Moreover, this breadth of physiological characteristics under investigation potentially highlights the physical nature of the sport and diversity in attributes needed to meet the physical demands of the game. It is well-established that rugby is a physical sport requiring participants to partake in challenging physical collisions such as scrummaging, tackling, aggressive mauling and rucking which require optimal muscular strength, power and endurance [5]. This gives rationale to the preponderance of studies investigating lower-and-upper body muscular power [15, 16, 30, 31, 32, 33, 34, 35, 36, 40, 49, 61, 64, 73], lower-and upper-body muscular strength [5, 7, 18, 27, 38, 42, 55, 56, 69, 78, 80] and muscular endurance [7, 15, 36, 81]. In addition, rugby players variably cover 5000 to 7000m during match play and engage intermittently in high-intensity efforts which require exceptional agility, anaerobic and aerobic capacity, speed, repeated sprinting and effort ability and generation of high levels of concentric and eccentric force production [53, 75]. This also provides justification for numerous studies investigating attributes such as speed, agility, prolonged high-intensity intermittent running ability, repeated sprint ability and explosive lower leg power [7, 16, 19, 30,31,32,33,34,35,36,37,38, 40, 49, 51, 53, 70, 72, 76].

Stage 1 findings also showed that almost all physiological characteristics had multiple tests for measurement. For example, this review showed that change of direction speed/agility is often evaluated using the 5-0-5, modified 5-0-5, Illinois Agility test, and change of direction speed test among other tests. However, it was surprising to discover that for all the tests identified in Stage 1, none had all the measurement properties (reliability, validity and responsiveness) investigated using rugby participants. In addition, of the 63 tests identified in Stage 1, only 21 had information on at least one of the measurement properties from rugby and related sports. This suggests that there is limited reporting of the measurement properties for tests commonly used in rugby in the literature. This was particularly evident for the property of responsiveness. All these findings are interesting and raise questions on the rationale for selection of tests by researchers in the field of rugby. For example, speed was the most commonly studied physiological characteristic in the included studies. It was frequently measured from linear distances varying between 5m and 60m (Table 4.1). The commonly tested sprinting distances for speed were, however, the 10-m, 20-m and 40-m. Professional rugby studies have provided the evidence that players seldom sprint distances greater than 40m in a single bout [100]. This probably justifies the predominance use of the 10m, 20m and 40m sprint tests in assessing rugby players in the literature [30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40]. In addition, straight-line sprinting is reported to be broken down into three phases: acceleration, attainment of maximal speed, and maintenance of maximal speed [101]. This is also possibly justifies the use of more than one sprinting distance for assessing speed as all these distinct qualities of speed should be evaluated separately. Although there could be plenty of reasons researchers prefer a specific test over others, literature generally recommends the use of feasible, reliable, valid and responsive tests [102]. This review found that there is dearth of high-quality studies (according to the COSMIN scoring system) investigating the measurement properties of speed tests using rugby participants. Best evidence synthesis only showed that there is limited evidence for the test-retest reliability and the known-group validity of the 5-m sprint test, 10-m sprint test and the 20-m speed test.

Repeated-sprint ability has also been reported to be extremely important in rugby given the high-intense and intermittent nature of the sport [100]. This review showed that the construct is commonly measured using the repeated 20-m sprint test and the rugby-specific repeated speed test. There were no high-quality studies found investigating the measurement properties of these tests in rugby. Only one study of "poor" methodological quality was found evaluating the test-retest reliability of the repeated 20-m sprint test using 12 rugby participants [51]. One needs to apply caution when adopting or using these tests in future studies using rugby players. High-quality future studies may need to explore the measurement properties of these tests. Repeated-sprint ability tests have been reported to underestimate the repeated high-intensity exercise demands of rugby [24]. To overcome the shortcomings of the repeated 20-m sprint test, Austin et al [24] assessed the reliability of three repeated high-intensity exercise tests specifically developed for backline players, RU forward players and RL forward players. The study was, however, rated as of "poor" methodological quality because of the small sample size per reliability analysis of each test and short interval (2 days) for the test-retest assessments.

There is dearth of high-quality studies investigating the measurement properties of the Yo-Yo intermittent recovery (Level 1 and 2) tests in rugby. This is despite the popularity of the tests in assessing prolonged high-intensity intermittent running ability/endurance and maximal aerobic power among rugby players [15, 24, 53, 54, 55, 56, 69]. This creates a need for future studies to specifically evaluate the measurement properties of the test using rugby participants. However, much of the information on measurement properties of these tests reported in rugby studies is referenced from validation studies conducted using participants from other sports. There are multiple studies providing the evidence of the measurement properties (reliability, validity and responsiveness) of the tests in other related intermittent sports such as soccer and Australian Rules football [88, 89, 91, 92, 93,94, 95, 96, 97, 98]. However, no high-quality studies were found evaluating the measurement properties of the test according to the COSMIN guidelines. All the studies included in this review assessing the measurement properties of the tests showed "poor" methodological quality. The major drawbacks in all these studies were mainly related to the issues of inadequate sample sizes and lack of a clear description of the expected hypotheses. There were also no studies evaluating the measurement properties of other tests of prolonged high-intensity intermittent running ability such as the repeated 12s sprint shuttle speed tests.

There were four tests identified estimating maximal aerobic power of rugby players: Multistage fitness, Yo-Yo intermittent recovery level 1 test, 30-15 intermittent fitness ($30\text{-}15_{IFT}$) and the 1 500m run. The multistage fitness was commonly used in a number of studies [7, 8, 10, 16, 27, 30,31,32,33,34,35,36,37, 40, 49, 50, 61,62,63,64]. However, there is paucity of information on the measurement properties for maximal aerobic power in rugby or related sports. Only one study of "good" methodological quality assessed the reliability and the usefulness of the 30-15 intermittent fitness in rugby participants [68]. Best evidence synthesis showed moderate evidence to support the test-retest reliability of the 30-15 intermittent fitness test. There were no high-quality studies providing evidence on the measurement properties of tests identified for measuring anaerobic endurance such as the T120s, Wingate 60 cycle, 300m shuttle run and the 400m sprint tests. Holloway et al [70] evaluated the validity of the T120s test and compared the validity of the test to the Wingate 60 cycle test. According to the COSMIN guidelines, the study was rated as of "poor" methodological quality as the study had 12 participants.

There were number of studies that evaluated agility/change of direction speed of rugby players. There tests commonly used included: 5-0-5 test, modified 5-0-5 test, Illinois agility test, change of direction speed test and agility test [6, 16, 19, 32, 34, 35, 40, 53, 74, 77]. There were no high-quality studies evaluating the measurement properties of these tests in rugby. This is despite the importance of agility as a physiological skill in the sport of rugby. There was only one study of "fair" methodological quality according to the COSMIN guidelines that evaluated the measurement properties of the 5-0-5 test, modified 5-0-5 test, and the L-run test. The study showed positive rating for the test-retest reliability of these three agility tests. However, there was negative rating for the known group validity for these tests. These findings support best evidence synthesis results indicating that there is limited evidence on the reliability and construct validity of these tests in assessing agility of rugby players. There is still need for further high-quality studies evaluating the measurement properties of these tests in rugby players.

Lower-body muscular power was the second most commonly studied physiological characteristic among rugby players in the studies included in this review. Although, there were three tests identified estimating the lower-body muscular power in the included studies. We found no studies evaluating the measurement properties of all three tests in rugby. Evidence on the measurement properties were found in one "fair" study evaluating the intra/inter-reliability and criterion validity of the Vertical Jump test among soccer players. A positive rating was found for the intra/inter-reliability of the test. Evidence on criterion validity was found to be questionable (Table 4.5) as there was no convincing argument that the gold standard test used was "gold". Overall, best evidence synthesis indicates limited level of evidence for the inter/intra-rater reliability and criterion validity of the sargent (vertical) jump test.

There were also no clinimetric studies found testing the measurement properties of tests for lower-body muscular strength, upper-body muscular strength and power. However, one study of fair methodology provided the evidence on the known-group validity of two tests of upper-body muscular endurance (bench press-repetitions-to-fatigue test at 60kg and 102.5kg). Best evidence synthesis indicates that there is limited evidence to support the validity of these two tests in evaluating upper-body strength-endurance.

4.5.1 Limitations

The results of this review paper should be interpreted with the understanding of a number of important limitations. Currently, there are no published reviews investigating measurement properties of performance-based tests measuring physiological characteristics in rugby. This renders comparisons with other review studies impossible. However, it suffices to suggest that these results expose a research gap on high-quality studies evaluating measurement properties for physiological tests commonly used in rugby. Although it could also be a major strength for this review, the inclusion criteria only considered full-text peer reviewed articles and completely excluded grey literature. This publication bias likely threatens internal validity of results obtained on measurement properties for this review as unpublished studies are more likely to report negative or unfavourable results. Although the COSMIN has been developed for the evaluation of measurement properties and has been generally used in the literature for that purpose, the guidelines appear well-suited and more applicable for appraising the quality of questionnaire-based studies. In the context of performance-based tests such as used in rugby, the applicability of the COSMIN as a quality rating tool for the studies on measurement properties still requires careful consideration.

4.6 Conclusion

This review identified 15 physiological characteristics commonly evaluated among rugby players. These include speed, repeated sprint and effort ability, repeated high-intensity exercise performance, prolonged high-intensity intermittent running ability, endurance, anaerobic endurance, maximal aerobic power and speed, agility, lower-body muscular power and strength, upper-body muscular strength and power and upper-body muscular endurance. The majority of these physiological characteristics had multiple tests for measurement. Overall, there is paucity of high-quality clinimetric studies evaluating measurement properties of commonly-used physiological tests in rugby. For those tests that had evidence on measurement properties, there was no test which was evaluated with respect to all measurement properties. More studies are required evaluating the measurement properties of the physiological tests commonly used in the sport of rugby. The 30-15 intermittent fitness test ($30\text{-}15_{IFT}$) test was the best rated test on maximal aerobic power with moderate evidence supporting its test-retest reliability. The 5-m, 10-m and 20-m speed test were the best tests assessing speed, however, with limited evidence supporting their test-retest reliability and the known-group validity. The 5-0-5 test, modified 5-0-5 test and L-run tests were the best tests for measuring agility but with limited evidence supporting their test-retest reliability. The vertical jump test was the best test for assessing lower-body muscular power, however, with limited level of evidence for inter-rater, intra-rater reliability and criterion validity. Furthermore, there is limited evidence on the known group validity of the upper-body strength endurance tests of bench-press repetitions-to-fatigue at 60 and 102.5kgs.

4.7 References

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5 CHAPTER 5: SECOND SYSTEMATIC REVIEW

5.1 Introduction

This chapter constitute the second systematic review presenting evidence on psychometric properties of commonly-used tests identified from literature for the assessment of rugby-specific game skills. The review was written in accordance to the published systematic review protocol (see Appendix H).

Open Access Review

BMJ Open Sport & Exercise Medicine

Psychometric evaluation of commonly used game-specific skills tests in rugby: A systematic review

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ABSTRACT

Objectives To (1) give an overview of commonly used game-specific skills tests in rugby and (2) evaluate available psychometric information of these tests.

Methods The databases PubMed, MEDLINE CINAHL and Africa Wide information were systematically searched for articles published between January 1995 and March 2017. First, commonly used game-specific skills tests were identified. Second, the available psychometrics of these tests were evaluated and the methodological quality of the studies assessed using the Consensus-based Standards for the selection of health Measurement Instruments checklist. Studies included in the first step had to report detailed information on the construct and testing procedure of at least one game-specific skill, and studies included in the second step had additionally to report at least one psychometric property evaluating reliability, validity or responsiveness.

Results 287 articles were identified in the first step, of which 30 articles met the inclusion criteria and 64 articles were identified in the second step of which 10 articles were included. Reactive agility, tackling and simulated rugby games were the most commonly used tests. All 10 studies reporting psychometrics reported reliability outcomes, revealing mainly strong evidence. However, all studies scored poor or fair on methodological quality. Four studies reported validity outcomes in which mainly moderate evidence was indicated, but all articles had fair methodological quality.

Conclusion Game-specific skills tests indicated mainly high reliability and validity evidence, but the studies lacked methodological quality. Reactive agility seems to be a promising domain, but the specific tests need further development. Future high methodological quality studies are required in order to develop valid and reliable test batteries for rugby talent identification.

Trial registration number PROSPERO CRD42015029747.

Key messages

What is already known

- Rugby players are required to have a set of favourable anthropometric properties and well-developed physiological qualities, combined with a range of game-specific skills, both offensive and defensive, to cope with the demands of the game.
- Anthropometric and physiological characteristics, like body mass, maximal leg strength and lower body muscular power, have been shown to differentiate between different rugby playing levels.
- Game-specific skills tests in rugby seem to have predicting value in discriminating talented and less talented players, but a review investigating the underlying psychometrics of these tests is lacking.

What are the new findings

- Reactive agility, tackling skills and simulated rugby games are the most investigated game-specific skills.
- For game-specific skills, there is mainly moderate to strong evidence for reliability and validity, but the studies lack methodological quality.
- Reactive agility tests seem to be very promising, based on the preliminary evidence on validity, reliability and feasibility.
- Future research should be focused on detailed and standardised studies of game-specific skills tests. These studies should include detailed reports of the study procedures, critical evaluation of test design and adequate sample sizes of n≥50 or a sample size calculation.
- These findings can impact the current practice in the way that researchers, scouts and coaches will critically evaluate the tests they use to identify talented players, start focusing on new game-specific skill domains and will come up with new tests in methodological rigorous studies to have an objective and psychometric sound backbone for their talent identification.

INTRODUCTION

Rugby is a diverse collision sport played all over the world on amateur, semiprofessional and professional levels.[1] Worldwide, it is played by >7 million players and the numbers are increasing.[2] The >2.47 million tickets sold during the World Cup Rugby 2015 and the estimated 120 million people watching the final highlighted the popularity of the sport.[3]

During the game, players participate in frequent bouts of intense activity, separated by short bouts of low-intensity activities.[4] The high-intensity activities include sprinting, physical collisions and tackles and low-intensity activities include walking and jogging.[4-6] During the course of a game, each team will

5.2 Background

Rugby is a diverse collision sport played all over the world on amateur, semi-professional, and professional level [1]. Worldwide, it is played by over 7 million players and the numbers are increasing [2]. The 2.47 million tickets sold during the 2015 World Cup Rugby and the estimated 120 million people who watched the final highlighted the popularity of the sport [3]. During the game, players participate in frequent bouts of intense activity, separated by short bouts of low-intensity activities [4]. The high-intensity activities include sprinting, physical collisions and tackles and low-intensity activities include walking and jogging [4-6]. During the course of a game, each team will perform on average 300 tackles, with semi-professional rugby matches being played at a mean intensity of 81 % VO_{2max} [7, 8].

To cope with these demands, rugby players are required to have a set of favourable anthropometric properties and well-developed physiological qualities, combined with a range of game-specific skills, both offensive and defensive [7-9]. Identifying young players who are promising to develop these prerequisites of the game requires rugby clubs to have efficient talent identification programmes [10, 11]. However, talent identification still remains mainly based on subjective assessments of scouts and coaches. To complement and increase the quality of this process, it would be beneficial to add a degree of objectivity by including sport science contributions on early talent predictors [11, 12]. This can be done by including specific tests in the talent identification process, which should be chosen based on proven potential to predict talent in a methodological responsible way.

Several studies investigated factors that potentially predict talent. In these studies, variables such as body mass, maximal leg strength, and lower-body muscular power were shown to differentiate between first and second division rugby league players [8, 13]. However, it remains questionable if the physiological qualities and anthropometric characteristics are the factors that discriminate between playing levels, since higher levels of strength, power or body mass do not directly relate to better performance during the game. Not every amateur rugby player that increases levels of strength, power or body mass becomes an elite rugby player. The well-developed physical qualities must be translated into improved playing performance to have practical significance [9]. Based on this, one presumes there should be additional, possibly even more important factors, which discriminate between talented and less talented players. In line with this, Gabbett et al [14] found that skill-related characteristics discriminated most between successful and less successful rugby league players, while physiological or anthropometric characteristics did not. These findings suggest an important role for game-specific skills in rugby, and specific tests can potentially identify talented players who are able to translate the physical qualities to improved playing performance.

The inclusion of objective talent predicting assessments requires multidimensional test batteries with the unique set of anthropometric characteristics and physiological and game-specific skills qualities that are required [15]. Different tests on talent predictors are available and used, but there are so far no overviews of the psychometric information underlying these tests and there is no gold standard yet. However, to be of added value in the process of talent identification, inclusion of tests should be based on objectivity, feasibility, validity and reliability. Additionally, a player should be measured at a young age and followed up for several years to investigate the progress of that specific variable in relation to the actual playing level, to judge if a certain variable has proven to be a talent predictor. However, studying talent predictors in this way requires longitudinal studies, which are generally expensive and time consuming and therefore often known group validity approaches are used. In known group validity approaches, groups that are known to differ or logically should differ are used and the test performance is compared over these groups [16].

With this taken into account, the addition of sport science contributions could only be beneficial to the talent identification process when tests with good reliability and validity are being developed, so they can be used as objective backbone for the subjective assessment of scouts and coaches. Therefore, it is required to have a clear overview of the available psychometric information of the commonly-used tests in rugby. An overview of these tests can guide researchers, scouts and coaches in the process of development or inclusion of objective tests in talent identification programs. In this review, we specifically focussed on game-specific skills tests in rugby as these tests have not been investigated in detail, specifically the underlying psychometrics. Besides the review about skills outcomes in different sports by Robertson et al [15], there are, to our knowledge, no available reviews about psychometrics of game-specific skills tests in rugby. Therefore, the aim of this review was to systematically evaluate the level of evidence on psychometric properties of measures of game-specific skills, used for males in rugby. Information from this review will guide selection of measurement instruments for future studies and assist scouts and coaches in knowledge about common usage of game-specific skills in literature and their psychometric properties. The review is divided into two steps:

i. First, the commonly used game-specific skills will be investigated to get an overview of the current situation in game-specific skills testing in rugby.

ii. Second, the available psychometrics of these tests and methodological quality of the studies will be analysed. The second step about the psychometrics will be the main focus of this review, while the first step will be used to put the psychometric information into perspective of what is commonly used in rugby.

5.3 Methods

5.3.1 Literature search

A systematic review of all published literature was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17]. A literature search for both steps was conducted on the databases *PubMed, Medline, CINAHL and Africa Wide* Information. Additionally, a hand search on the reference lists of included articles for the second step was done. The two steps varied in included articles because of an additional category in the search terms for the second step. The search terms for the first step included keywords of (*1) game-specific skills, (2) age categories, (3) sports* and *(4) assessment tools*. With these keywords game-specific skills tests could be found, without taking into account psychometric information. To find studies reporting psychometric information on these tests, an additional category of keywords was included in the second step. This was an extra category including keywords about (5) psychometric properties. The specific keywords of both categories can be found in Appendix N.

5.3.2 Selection criteria

English articles published between January 1995 and March 2017 was included. Only studies containing male subjects playing rugby league or rugby union were included. Opposed to the initial criteria set in the protocol (Appendix H), we did to not include Australian Football players. The gameplay and required game-specific skills for these sports differ too much to make fair comparisons between these sports. No limitations were made for study design and age category. However, editorials, book chapters, poster and oral conference abstracts, unpublished theses, dissertations and case studies were excluded. Furthermore, studies published in non-English language and studies involving rugby participants living with disabilities were excluded.

Studies in the first step, about commonly used game-specific skills tests, had to report detailed information about the construct and testing procedure of at least one game-specific skill. Game-specific skills were defined as skills that directly relate to better performance during the game. These include, but are not limited to, ground skills, side-stepping, reactive agility, aerial and ground kick, passing-for-distance, passing-for-accuracy, kicking, and catching (while moving) [18]. Studies included in the second step, about psychometric information, should have reported also on at least one psychometric property evaluating reliability, validity or responsiveness.

5.3.3 Selection process

Two reviewers (MC and SO) independently screened titles, abstracts and full texts to assess inclusion or exclusion based on the predefined criteria. In case of disagreement, the reviewers discussed until consensus was reached. Otherwise disagreements were resolved through discussion or referral to a third reviewer (BSE). The full texts of titles and abstracts deemed potentially relevant were retrieved and reviewed for inclusion.

5.3.4 Data synthesis

The following data were extracted: publication details (first author, year of publication), title, purpose of the study, age of the participants, test groups, rugby code, game-specific skill construct evaluated, test(s) used to measure the construct, measurement properties assessed (reliability, validity and responsiveness), evidence level and Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) rating. For the reliability results, strong evidence was indicated with intraclass correlation coefficient (ICC) ≥0.70, Pearson's correlation coefficient (PCC) ≥0.80 or Cronbach's alpha ≥0.70. For the validity results, the low effect size (ES) were indicated as weak evidence and high ES as strong evidence. Weak evidence was determined with ES 0.2–0.49, moderate evidence with ES 0.5-0.79 and strong evidence with ES ≥0.8. Studies reporting validity results in ω^2 were assessed based on criteria set in that specific study as no assessment of the ω^2 is available in the COSMIN.

5.3.5 Risk of bias assessment

The methodological quality of the selected articles in the second step was assessed using the COSMIN checklist by two independent reviewers (MC and SO) [19]. This checklist was developed to rate the methodological quality of a study on one or more measurement properties. The rating is based on a point rating scale (poor, fair, good or excellent) on different items of design requirements and expected statistical methods. The overall rating for the methodological quality is indicated by the lowest score of these items.

5.4 Results

5.4.1 Search results

In the initial procedure of the first step, 287 articles were retrieved. After removal of duplicates, screening the records and assessing full texts of potential studies, 30 articles were included in this step (Figure 5-1).

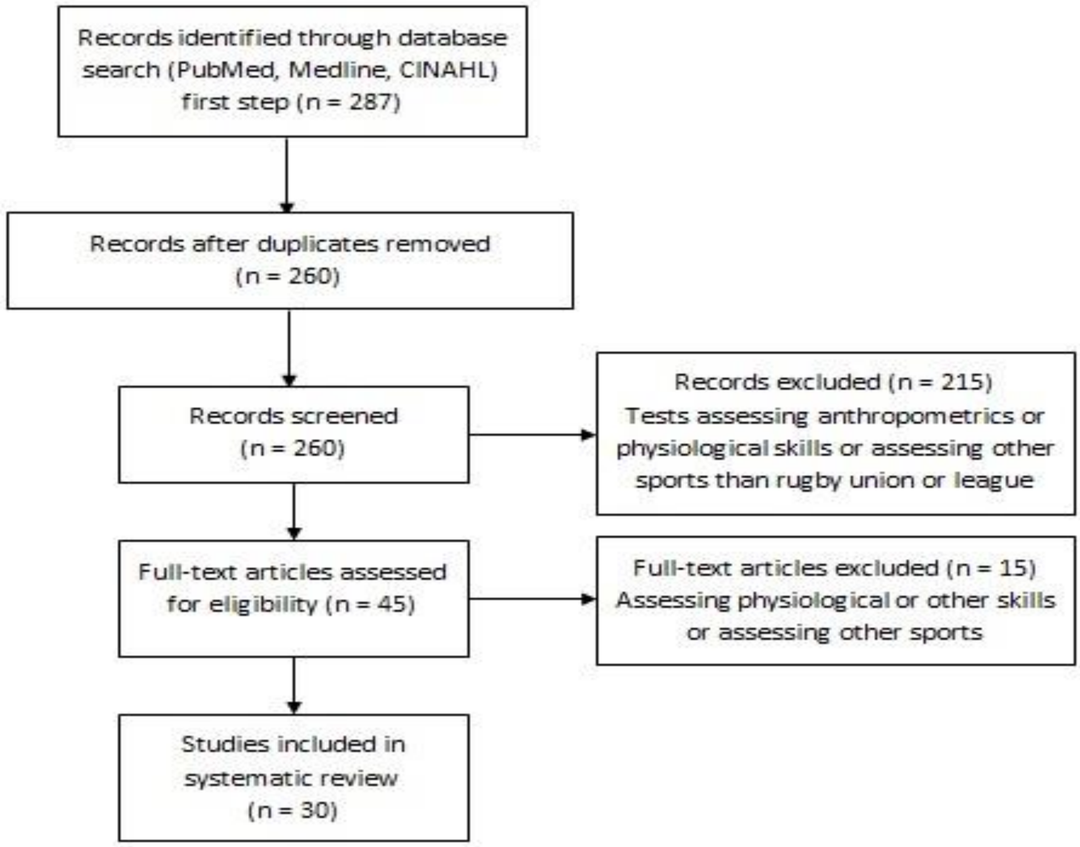

Figure 5-1: PRISMA flow diagram showing search strategy for first step

The initial procedure in the second step delivered 64 articles. After removal of duplicates, screening the records and assessing full texts of potential studies, 10 articles were included. The flow diagram for search results and study selection is illustrated in Figure 5-2.

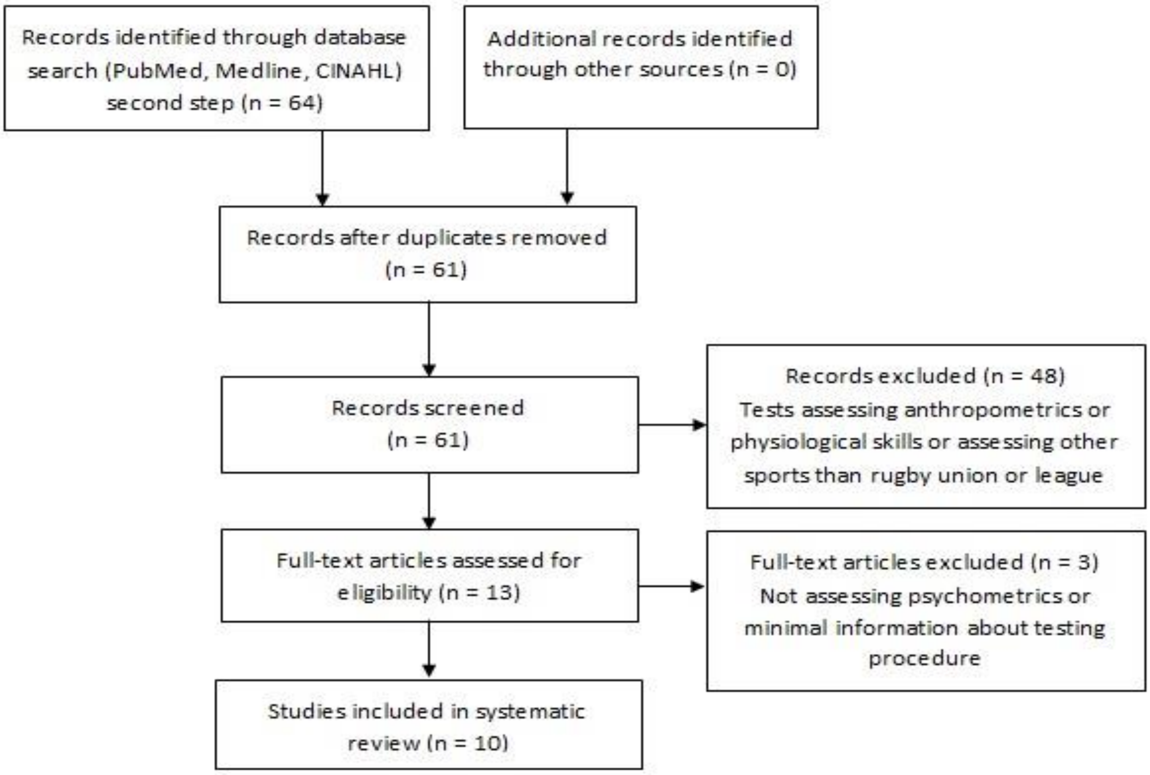

Figure 5-2: PRISMA flow chart search strategy for second step

5.4.2 Step 1: commonly used tests

An overview of the indicated game-specific skills and subjects used is shown in Table 5-1. Reactive agility and tackling skills were the most investigated skills, assessed both in seven articles. Three articles tested multiple skills. Articles assessed game-specific skills both in training setting and during match play. Two articles in training setting reported specifically on multiple skill-based tests, which were reactive passing and tackling under fatigue [20, 21]. Of the 30 articles, 18 articles used rugby league players, 10 articles used rugby union players and 2 did not specify the rugby code.

Table 5-1: Overview of game-specific skills found in studies included in first step

First author (year)	Skill tested	Rugby code
Green (2011) [25]	Reactive agility	Union
Serpell (2010) [26]	Reactive agility	League
Serpell (2011) [29]	Reactive agility	League
Gabbett (2008a) [24]	Reactive agility	League
Gabbett (2009) [33]	Reactive agility	League
Gabbett (2011a) [9]	Reactive agility, pattern prediction/recognition, tackling, catching, passing	League
Gabbett (2011b) [34]	Reactive agility, pattern prediction/recognition, tackling, catching, passing	League
Pavely (2009) [20]	Reactive passing	Union
Usman (2011) [35]	Tackling	Union
Gabbett (2008b) [31]	Tackling	League
Gabbett (2016) [21]	Tackling under fatigue	League
Waldron (2014) [36]	Tackling, catching and passing	League
Lacome (2016) [37]	Tackling and passing during match	Union
Wu (2007) [38]	Scrimmage	Not specified
Pienaar (1998) [10]	Catching and passing	Union
Vaz (2012) [39]	Simulated rugby games	Union
Higgings (2012) [40]	Simulated rugby games	Union
Stuart (2005) [22]	Simulated rugby games	Union
Gabbett (2010) [41]	Simulated rugby games	League
Sirotic (2011) [42]	Game-specific skills per minute during match	League
Sirotic (2009) [27]	Game-specific skills per minute during match	League
Kempton (2013) [28]	Game-specific skills per minute during match	League
Bennett (2016) [23]	Skill involvement during match	League
Lacome (2017) [43]	Skill involvement during match	Union
Linthorne (2014) [44]	Rugby kick	Not specified
Cockcroft (2016) [45]	Rugby kick	Union
Gabbett (2012) [46]	Two-on-one attacking drill	League
Gabbett (2011c) [47]	Two-on-one attacking drill	League
Gabbett (2007) [14]	Playing ability assessed by coach	League
Gabbett (2008c)[48]	Playing ability assessed by coach	League

5.4.3 Step 2: Psychometrics

5.4.3.1 Description of included studies

The 10 included articles in the second step reported in total on 49 variables of psychometrics. Seven articles assessed rugby league players and three articles rugby union players. Four studies assessed reactive agility, whereby Gabbett et al [9] also assessed other technical and perceptual skills. Also four studies assessed game-specific skills during a match. The other three studies focused on other technical or game-specific skills, like passing and tackling. Between articles reporting on the same skill, test designs differed in set-up, assessment and subjects used. Studies ranged from 9 to 218 subjects, with reported age ranging from 16.5±1.0 to 25±4 years [22, 23]. Subjects varied from first to second grade, elite senior to elite junior and experienced to non-experienced players.

5.4.3.2 Reactive agility

Gabbett et al [24] and Gabbett et al [9] used the same test design, with players required to follow direction of tester initiated movement to left or right through finish gate. Green et al [25] used the design where players were required to sprint to 45° change of direction point and change direction to left or right flashing finish gate. And Serpell et al [26] used a completely different design and asked players to sprint towards a screen displaying action of sport-specific movement and change direction as playing defender.

5.4.3.3 Game-specific skills during match

The game-specific skills during match were all analysed after the match by an expert analyst and tested on inter-rater or intra-rater reliability. Gabbett et al [14] let two expert coaches assess playing skills (general, evasion, tackling/defensive, offensive) on standardised criteria. Kempton et al, Sirotic et al and Bennett et al all coded specific events [23, 27, 28]. Kempton et al [28] coded kicks received, passes, ‘dummy-half’ pass, ball caries and kicks (attacking and for territory). Sirotic et al [27] assessed ball caries, support runs, touches of the ball, play-the-balls and tackles made. Bennett et al [23] coded the ball caries, support runs, offensive misses, line breaks, line break assists and tackles completed or not completed.

5.4.3.4 Simulated rugby games and catching and passing

Furthermore, Stuart et al [22] assessed simulated rugby games, focused on different forms of sprinting, kicking and passing. Pienaar et al [10] analysed passing-for-distance, passing-for-accuracy over 4 and 7 m and catching while running. An overview of all characteristics of the included studies is illustrated in Table 5-2.

Table 5-2: Study characteristics and test design regarding studies included in the second step

Author (year)	Rugby code	Skill tested	Subjects	Age (mean ± SD)	Test design
Green (2011) [25]	Union	Reactive agility	Academy (n=17)	19 ± 1.67	Sprint to 45° change of direction point and change direction to left or right flashing finish gate.
			Club (n=11)	19 ± 1.30	
Gabbett (2008a) [24]	League	Reactive agility	First grade (n=12)	23.6 ± 2.3	Follow direction of tester (4 scenarios) initiated movement to left or right through finish gate.
			Second grade (n=30)		
Serpell (2010) [26]	League	Reactive agility	Elite (n=15)	Not reported	Sprint towards screen displaying action of sport-specific movement (48 scenarios) and change direction as playing defender.
			Elite junior (n=15)		
Gabbett (2011a) [9]	League	Technical and perceptual skills	First grade (n=58)	23.8 ± 3.8	Reactive agility: follow direction of tester (4 scenarios) initiated movement to left or right through finish gate
					Pattern recall: recall player positions at time of video footage occlusion
					Pattern prediction: predict next action at time of video footage occlusion
					Tackling: 1-on-1 tackling drill assessed on standardized criteria by sport scientist
					Draw and pass: 2-on-1 drill in single and dual-task conditions assessed by sport scientist
Pienaar (1998) [10]	Union	Catching and passing	Experienced (n=173)	Not reported	Passing for distance: passing as far as possible
			Non-experienced (n=45)		Passing for accuracy: passing over 4 and 7 meter towards target
					Running and catching: catching the ball while running
Stuart (2005) [22]	Union	Simulated rugby games	Elite (n=9)	25 ± 4	Kick for distance: kicking as far as possible
					Kick-off for distance: kicking-off as far as possible

					Offensive sprint: forward run with ball while swerving Defensive sprint: running forward and backward three arcs Tackle sprint: tackle on tackle bag, running backward with ball, making another tackle and run forward Passing accuracy: repeatedly pass ball as fast as possible towards target
Gabbett (2007)[14]	League	Game-specific skills during match	First grade (n=86)	22.5 ± 4.9	Two expert coaches assessing playing skills (general, evasion, tackling/defensive, offensive) on standardized criteria
Kempton (2013) [28]	League	Game-specific skills during match	Elite (n=5)	Not reported	2x first halves of 10 subjects coded on game-specific skills analysed on standardized criteria by trained operator from recordings of matches
			Elite junior (n=5)		
Sirotic (2009) [27]	League	Game-specific skills during match	Elite (17)	24.8 ± 3.1	2x first halves of 9 matches analysed on game-specific skills per minute of playing time
			Semi-elite (22)	22.1 ± 2.4	
Bennett (2016) [23]	League	Game-specific skills during match	Elite junior (45)	16.5 ± 1.0	2x first halves of 8 matches analysed on skill involvement during match

5.4.3.5 Risk of bias assessment

Reliability and validity outcomes were the only risk of bias assessment data that were described in detail in the included articles in the second step. No details on other risk of bias assessment variables were given. Therefore, only outcomes on these two factors of the risk of bias assessment were evaluated.

5.4.4 Reliability outcomes

All 10 articles included in the second step reported reliability outcomes. Five articles reported test–retest reliability, four articles intra-rater reliability and one article both inter-rater and intra-rater reliability. Also, 27 of the 33 reliability outcomes indicated strong evidence, with the highest ICCs for intra-rater reliability of 1.00 on line break assists and tackles completed during a match [23]. Only Serpell et al [26] indicated two ICCs of ≤0.5 on perception and response time and confidence rating for test–retest reliability in a reactive agility test. The ICC was the most used analysis; PCC and Cronbach's alpha were both used once. Stuart et al [29] reported coefficient of variation (CV), which indicated the level of dispersion around the mean. However, there is no COSMIN guideline for assessing CV. In two studies, CVs were <10%, and in two studies they found CVs >10%. Five of the articles were found to be of poor and five of fair methodological quality. The main reasons for this were missing information about percentage and handling of missing items, small sample size and methodological flaws. Methodological flaws included missing information on the participants, unclear study design and missing information on the retest situation in test-retest setting or about the second rater in inter-rater setting. The reliability outcomes are illustrated in Table 5-3

Table 5-3: Reliability outcomes of studies included in second step

Author	Rugby code	Skills tested	Subject (n)	Reliability	Variable	Results	Evidence	COSMIN
Green (2011) [25]	Union	Reactive agility	11	Test-retest	Reactive agility speed (s)	ICC = 0.88, SEM = 0.09	+	Poor
Gabbett (2008a) [24]	League	Reactive agility	42	Test-retest	Movement time (s)	ICC = 0.92, TE = 2.1%	+	Fair
					Decision time (ms)	ICC = 0.95, TE = 7.8%	+	
					Response accuracy	ICC = 0.93, TE = 3.9%	+	
Serpell (2010) [26]	League	Reactive agility	15	Test-retest	Total agility time (s)	ICC = 0.82, SEM = 0.01	+	Fair
					Perception and response time (s)	ICC = 0.31, SEM = 0.01	-	
					Participants' confidence about decision made (%)	ICC = 0.50, SEM = 2.12	-	
Gabbett (2011a) [9]	League	Technical and perceptual skills	58	Test-retest	Tackling assessment	ICC = 0.83, TE = 3.3%	+	Poor
					Draw and pass assessment	ICC = 0.86, TE = 5.3%	+	
					Reactive agility, decision accuracy	ICC = 0.93, TE = 3.9%	+	
					Reactive agility, decision time	ICC = 0.95, TE = 7.8 %	+	
					Pattern recall	ICC = 0.80, TE = 9.3%	+	
					Pattern prediction	ICC = 0.85, TE = 8.7 %	+	
				Intra-rater	Playing performance	ICC > 0.80, TE < 5.0%	+	
Pienaar (1998) [10]	Not specified	Catching and passing	36	Test-retest	Passing for distance	PCC = 0.74	-	Fair
					Passing for accuracy, 7 m	PCC = 0.66	-	
					Passing for accuracy, 4 m	PCC = 0.39	-	
					Running and catching	PCC = 0.53	-	
Stuart (2005) [22]	Union	Simulated rugby games	9	Between-subjects CoV	Offensive sprint	CV = 13%		Poor
					Defensive sprint	CV = 9.2%		
					Tackle sprint	CV = 9.8%		
					Passing accuracy	CV = 20%		

Gabbett (2007) [14]	League	Game-specific skills during match	86	Intra-rater		ICC = 0.85 - 0.98, TE = 5.1 - 5.3%.	+	Poor
				Inter-rater		ICC = 0.84 - 0.94,TE = 7.0 - 9.0%	+	
Kempton (2013) [28]	League	Game-specific skills during match	10	Intra-rater	Attempted tackle	α = 0.81	+	Poor
					Kick receive			
					Pass			
					'dummy-half' pass			
					Ball carry			
					Kick (attacking)			
					Kick (territory)			
Sirotic (2009) [27]	League	Game-specific skills during match	39	Intra-rater	Ball carries	ICC = 0.996,TEM = 0.008	+	Fair
					Support runs	ICC = 0.986, TEM = 0.010	+	
					Touches of the ball	ICC = 0.997,TEM = 0.022	+	
					Play-the-balls	ICC = 0.997,TEM = 0.008	+	
					Tackles made	ICC = 0.991, TEM = 0.015	+	
Bennett (2016) [23]	League	Game-specific skills during match	45	Intra-rater	Ball carry	ICC = 0.98, TEM = 0.053	+	Fair
					Support run	ICC = 0.86, TEM = 0.077	+	
					Offensive miss	ICC = 0.71, TEM = 0.061	+	
					Line break	ICC = 0.86, TEM = 0.007	+	
					Line break assist	ICC = 1.00, TEM = 0.000	+	
					Tackle completed	ICC = 1.00, TEM =	+	

		0.064	
	Tackle not-completed	ICC = 0.99, TEM = 0.000	+

ICC =Intraclass correlation coefficient, PCC =Pearson's correlation coefficient, SEM =Standard error of measurement, TE =Typical error of measurement, TEM Technical error of measurement, α= Cronbach's alpha, CV= Coefficient of Variation, (m)s (mili)seconds, '+' strong evidence; '-' limited evidence; COSMIN=consensus-based standards for the selection of health measurement instrument

5.4.5 Validity outcomes

Four articles reported construct validity outcomes based on known group evaluations (Table 5-4). Different groups were compared; from experienced to non-experienced and elite to elite youth. Three articles assessed reactive agility, reporting Cohen's d ES, and one article assessed passing, running, catching and kicking skills, reporting ω^2. Practical significance was determined at $\omega^2 \geq 14\%$ on the basis of assessment by Pienaar et al [10]. Four of the six ES on different variables of the reactive agility tests indicated moderate evidence and one ES indicated strong evidence. Highest was an ES of 1.14 found by Green et al [25] on reactive agility speed compared between academy and club rugby union players. Lowest ES (0.34) indicated weak evidence, which was on response accuracy in a reactive agility test compared between first-grade and second-grade players, by Gabbett et al [24]. The ω^2 values varied from 10.6% for the passing for accuracy test on 4 m to 50.7% on the passing for accuracy test on 7 m. Furthermore, all studies indicated fair methodological quality according to the COSMIN checklist. Main reasons were missing information on percentage and handling of missing items, low sample sizes and methodological flaws. Methodological flaws included missing information on the participants, unclear study design and missing information on how the validity results were determined.

Table 5-4: Validity outcomes of studies included in the second step

Author	Sport	Domain	N	Known groups	Variable	Result	Evidence	COSMIN
Green [25]	Rugby Union	Reactive agility	28	Academy vs. club	Reactive agility speed (s)	ES = 1.14	++	Fair
Gabbett [24]	Rugby League	Reactive agility	42	First grade vs. second grade	Movement time (s)	ES = 0.73	+	Fair
					Decision time (ms)	ES = 0.54	+	
					Response accuracy	ES = 0.34	-	
Serpell [26]	Rugby League	Reactive agility	30	Elite players vs. elite youth players	Total agility time (s)	ES = 0.56	+	Fair
					Perception and response time (s)	ES = 0.68	+	
Pienaar [10]	Rugby	Rugby skills	218	Experienced vs. non-experienced	Passing for distance (m)	ω^2 = 32.4	+	Fair
					Passing for accuracy, 7 m	ω^2 = 50.7	+	
					Passing for accuracy, 4 m	ω^2 = 10.6	-	
					Running and catching	ω^2 = 23.3	+	
					Kick for distance (m)	ω^2 = 29.4	+	
					Kick-off for distance (m)	ω^2 = 13.9	-	

ES= Effect size, ω^2 =Omega-square, '++' strong evidence, '+' moderate evidence, '-' weak evidence, COSMIN=Consensus-based standards for the selection of health measurement instrument

5.5 Discussion

The present systematic review investigated existing game-specific skills tests and evaluated available psychometrics of these tests. The main finding was that studies on these tests mainly indicated moderate to high evidence for reliability and validity. However, articles assessing psychometrics often lacked methodological quality (Tables 5.3 and 5.4). Therefore, it still needs to be confirmed if the tests are really valid and reliable in more methodologically rigorous studies specifically designed to evaluate psychometric properties. Since the findings of the present review can be influenced by the procedures followed in the included studies (e.g., incomplete description of the procedure, low sample sizes, data handling), the reported reliability and validity results should be interpreted with caution. The results of this systematic review can help researchers, scouts and coaches in the process of development or inclusion of objective game-specific skills tests in talent identifying programmes in rugby clubs.

5.5.1 Game-specific skills

In the first step of this systematic review, 30 articles reporting on game-specific skills were included. Reactive agility, tackling skills and simulated rugby games were the most studied skills. Reactive agility is defined as 'a rapid whole body movement with change of velocity or direction in response to sports specific stimuli [29]. Tackling and simulated rugby games were tested using multiple different set-ups, assessments and analyses. In the second step, 10 articles were included, in which reactive agility also was the most assessed skill. In these studies, mainly test–retest and intra-rater reliability were assessed. The majority of these studies indicated strong reliability evidence, meaning that the tests were relatively consistent over different occasions or raters. Also, 4 of the 10 articles reported validity outcomes with ES, using known group comparison. In these studies, moderate to strong evidence was found for different reactive agility tests. None of the studies reported on comparison with some kind of gold standard, and for most game-specific skill domains there is no gold standard yet. With only four studies reporting validity there is a clear need for validity analyses of game-specific skills tests. Before tests can be of benefit in the talent identification process, their predictive validity should be known, otherwise the implication of a specific score on these tests do not give meaningful insights with practical validity.

The strength of this systematic review was the use of the COSMIN checklist for the assessment of methodological quality of the articles. This assessment for articles reporting on reliability resulted in five articles indicated with poor and five articles with fair methodological quality. All articles reporting on validity scored fair on methodological quality, according to the COSMIN. These low scores were mainly caused by low sample sizes, methodological flaws that were not properly addressed and lack of information about percentage and handling of missing items. The low methodological quality could be the result of the finding that most studies were not specifically designed to assess psychometrics. The studies primarily focused on relations between test outcomes and playing groups. Assessing psychometrics seemed to be a side issue, causing minimal details on testing procedures. Therefore, we recommend researchers to come up with detailed and standardised studies of game-specific skills tests in rugby. These studies should include detailed reports of the study procedures, critical evaluation of test design and adequate sample sizes of n≥50, according to the COSMIN guidelines, or a sample size calculation. These recommendations are challenging to apply in the real world, but are necessary to come up with studies with high methodological quality and be able to work towards a better underlayment of the game-specific skills tests.

5.5.2 Psychometrics

The included articles varied in test design, subjects and statistical analyses used. Therefore, comparison of psychometrics over different studies was difficult. For example, three different protocols were used in four reactive agility tests. These studies used different cues to react on, like flashing timing gates, directions of a tester or a screen displaying sport-specific actions. Arguably, different outcomes are found when different test designs or groups are compared. Therefore, standardisation and detailed reporting is required. Furthermore, objective guidelines for interpretation of outcomes should be developed, taking into account the specific age and playing position groups. These guidelines have to be based on game requirements for the playing groups, which can be followed by developing levels of minimal requirements for the different groups. For determining these guidelines, promising techniques like Global Positioning System tracking and video analyses can be used.

Some interesting findings of the studies included in the second step were that the passing tests of Pienaar et al [10] and Stuart et al [22] seemed to have difficulties to establish good reproducibility, based on the low PCCs of 0.39 and 0.74 of Pienaar et al [10] and the high CV of 20% for passing accuracy in the study of Stuart et al [22]. Also differences were found between studies using reactive agility tests. Serpell et al [26] indicated weak correlations between test and retest measurement in elite youth rugby league players for perception and response time and confidence rating (ICC=0.31 and 0.50, respectively). Although, a strong correlation (ICC=0.82) on the test and retest measurement for total reactive agility time was found. This could be the result of players reacting differently on the cues in the test and retest, while keeping their total reactive agility time relatively constant. However, Gabbett et al [24] contradict this finding because they found strong correlations between the test and retest of their reactive agility test for both decision time and response accuracy, with ICCs of 0.95 and 0.93, respectively. Furthermore, Pienaar et al [10] found large differences between the performance of experienced and non-experienced players on passing for accuracy over 4 and 7m, respectively, ω^2 of 10.6% and 50.7%. The difference in the passing test was only 3 m, but the passing test over 7m had the ability to better discriminate between experienced and non-experienced players than the passing test over 4 m. However, it remains unclear if this difference in discriminant power between the 4 and 7 m passing test of Pienaar et al [10] resulted from different test design, subject selection, technique or other reasons.

Comparison of the reliability and validity outcomes resulted in some relatively low reliability and high validity outcomes found on the same test. This happened mainly on reactive agility and passing tests. For example, Pienaar et al [10] found in their passing for accuracy test over 7 m a relatively low PCC of 0.66 for the test–retest situation, but a relatively high ω^2 of 50.7% for the discriminative validity between experienced and non-experienced players. This indicated the ability to discriminate between different groups, but groups showed inconsistent patterns over different test occasions. Therefore, stricter procedures could be developed to decrease variability. Moreover, it would be of interest to gain information about decisions made by the same player in the same situation or about decisions made by different players in a similar situation. This 'inter-player' and 'intra-player' reliability could be important, especially in reactive agility tests to evaluate decision-making patterns of specific players. Possibly this decision-making ability differs between playing levels and can partly explain the difference between talented and less talented players.

5.5.3 Reactive agility

Of all the different game-specific skills that were assessed, reactive agility seems to be the most promising skill to discriminate between different playing groups. Outcomes of studies analysing reactive agility revealed that higher-skilled players have faster decision-making and change of direction compared with lower-skilled players. Serpell et al [26] argued that high-performance players are able to identify key sport-specific kinematic cues earlier than low-performance players and therefore can react quicker. These predictive features in highly skilled players make it more difficult to tackle them in attacking play or make it easier for them to adapt to opponent movements in defensive play. Besides the requirement of high methodological quality studies on this skill, all forms of validity and reliability, and the underlying principle of the skill should be further investigated. With critical evaluation and expert consensus, a gold standard for reactive agility can be developed, which can be used as reference test for new developments in this game-specific skill. Ecological validity should be taken into account in these tests, with Serpell et al [20] being promising by using videos of real-time game situations as cues to react on. The lack of ecological valid tests is also highlighted by the fact that no studies assessed validity in match play situations. These factors should be considered when new tests are developed or existing tests are adapted.

5.5.4 Limitations

Like all systematic reviews, the quality of this review is dependent on articles identified and included. MeSH terms were not used for all possible search terms in the search strategy of this review, which could have led to missed information. On this specific topic there were limited data available, which made it hard to draw strong conclusions. It can be argued that studies on sports comparable to rugby, like American and Australian football, should have been included, but inclusion of these sports would have implied unfair comparisons, based on significant differences in rules and gameplay. Furthermore, it should be considered that most articles assessed rugby league players. This can partly be explained by the relatively high amount of studies of Gabbett et al, which studied rugby league only. Possibly, this could have biased the results towards tests more focused on rugby league, without taking into account the minor differences between both rugby codes, like the contest after a tackle, points scored with specific actions and the 'six tackle rule'. Another limitation is the inclusion of articles with athletes from all age ranges as this could have led to unfair comparisons. This was due to the limited articles available and the focus of this review to analyse all the literature available on this topic. Readers or coaches should note that when using information about psychometric data from game-specific tests in this review it needs to be established whether the participants involved in such reported studies share similar characteristics to the populations the results are applied to. As a last point, it should be considered for future studies if the COSMIN rating as being used in this review is the best way to assess the methodological quality of the studies. Potentially other, more correct analyses or definitions are available.

5.5.5 Future directions

For future studies, we recommend researchers to differentiate between playing positions (groups) and to study game-specific skills in situations that mimic actual game situations. Now most skills are assessed in isolated and standardised settings. However, based on the gameplay of rugby it is suggested that additional skills are important, for example, skill performance while being fatigued. Logically, the closed skill of, for example, passing is useful, but potentially passing skills while fatigued is even more important. As fatigue has shown to influence tackling ability, with fatigue resulting in progressive reductions in tackling technique, this could also be the case for passing skills [21, 30]. During most game phases, and especially the end of the second half, there is a level of fatigue among the rugby player passing the ball. A suggestion for testing these skills with and without the influence of fatigue could be to perform a passing test, both before and after a maximal endurance test. Furthermore, an additional skill that seems to be important is the ability to 'read the game'. A player that reads the game well is better in avoiding situations with risk on being tackled, can better create attacking opportunities and can reduce situations of making passing or kicking mistakes. Moreover, a player can have an excellent reactive agility score in an isolated testing situation, but if the player makes wrong decisions during the game about where to run and constantly runs into ‘traffic’, the player has no benefit of his excellent reactive agility score. Potentially, a player with a lower reactive agility score, but with better ability to read the game, is more successful during a game. This is in line with the findings from Gabbett et al [31], which found that rugby league players with poor reactive agility scores had a lower risk of injury. They suggested that these players might inadvertently avoid the heavy collisions that result in injury, or at best result in partial contact that does not result in exposure to the full force of a tackle, because of their low reactive agility. It can be that this was also due to the better ability to read the game, which makes this an interesting variable to assess in further studies.

With these findings taken into consideration, we recommend a change of direction in game-specific skills testing in rugby before tests are further developed. Because there are no high methodological quality studies, which analyse validity and reliability, there is a need for more methodologically rigorous studies, specifically designed to evaluate psychometric properties of game-specific skills tests. Otherwise it is unclear to what extent the findings of studies assessing game-specific skills are influenced by the test procedures followed. Because of the limited studies on validity found, there should be more studies focusing on the validity of these tests to be able to place the results in the context of predictive value for talent identification. Furthermore, it should be analysed if the currently used game-specific skills tests are clear reflections of the requirements of the game. Potentially a new view on testing and new categories of testing should be developed. Only after addressing these features in game-specific skills testing, we then recommend analysing game-specific skills in the way it is currently done. After this consideration, game-specific skills tests can be included as objective tests to complement talent-identifying programmes in rugby clubs.

5.6 Conclusion

Articles assessing psychometrics of game-specific skills tests mainly indicated moderate to high evidence on reliability and validity measures, but the studies lacked methodological quality. Future research should focus on high methodological quality studies to indicate valid and reliable game-specific skills tests in rugby, preferably focused on specific playing positions. Reactive agility is the most studied and promising skill, and should be further investigated to find the best testing procedure and create a gold standard. This systematic review can help researchers, scouts and coaches in the process of development or inclusion of objective game-specific skills tests in talent identifying programmes in rugby clubs, which can function as an objective backbone for talent identification by scouts and coaches.

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6 CHAPTER 6: VALIDATION AND FEASIBILITY STUDY

6.1 Introduction

This chapter presents results for phase II which was ultimately concerned about refining the assembled first version of the SCRuM test battery. To that effect, this chapter presents a research publication[4] on a study conducted to investigate the face validity, logical/content validity and practical feasibility of the test items included in the first version of the SCRuM test battery. Most importantly, the paper described the interplay of factors considered in the final selection of anthropometric, physiological characteristics and rugby-specific game skills and their corresponding tests for inclusion in the first version of the SCRuM test battery.

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RESEARCH ARTICLE

Logical validation and evaluation of practical feasibility for the SCRuM (School Clinical Rugby Measure) test battery developed for young adolescent rugby players in a resource-constrained environment

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Abstract

There is a growing impetus towards usage of test batteries in talent identification (TID) programmes in rugby. Consequently, there are many test batteries in existence profiling anthropometric, physiological characteristics and rugby-specific skills. There is no consensus in the literature on the constituent variables and corresponding tests required to inform TID programs. Following development of a new test battery called the SCRuM (School Clinical Rugby Measure), this study aimed at establishing face, logical validity and practical feasibility of included tests. The test battery, initially comprised of 23 items, had its face and logical validity evaluated by five (5) adolescent rugby coaches and 20 rugby experts, respectively. Logical validation was conducted in two questionnaire-based rounds with Content Validity Index (I-CVI) calculated for each variable. Subsequently, a cross-sectional study targeting 30 local rugby coaches was conducted to determine the perceived practical feasibility of each test item. The results showed excellent I-CVI (>0.78) for 17 variables (speed, weight, height and skin fold measures, repeated high-intensity exercise performance ability, prolonged high-intensity intermittent running ability, change of direction speed, anaerobic capacity, lower-and upper body muscular power and strength, muscular flexibility, reactive agility, passing for accuracy, tackling proficiency, and catching). However, three tests, namely, Reactive Agility, One Repetition Maximum Back Squat and One Repetition Maximum Bench Press had low test-feasibility indices (T-FI< 35) suggesting practicality concerns with implementation in the Zimbabwean context. Thus, these findings suggest the need for substitution or development of new practically feasible tests for upper-and lower body muscular strength and reactive agility.

6.2 Background

Rugby union (rugby) is a popular sport even in countries hardly known for competitive rugby such as Zimbabwe [1, 2]. With the advent and subsequent global spread of professionalism in rugby since 1995 [3], an increased number of adolescents are participating either professionally or otherwise in this physically demanding collision sport worldwide [4]. Possibly, with continued professionalism and increased demand for young competent rugby players with potential to become successful future elite athletes, the number of young players is likely to increase and also efforts directed towards identifying and recruiting young rugby players will heighten universally [3-6]. Central to the process of talent identification (TID) and recruitment of young rugby talent is the development and usage of screening test batteries composed of variables reflecting the key requirements of rugby and practically feasible tests with acceptable psychometric properties [7-14]. Currently, there is no general consensus in the literature on the ideal constituent variables and the corresponding tests that should be included in test batteries designed to inform TID. Consequently, existing test batteries are varied in composition having dissimilar tests assessing similar construct variables. This is a significant shortcoming when comparison data profiling young rugby players is needed.

Despite the complexity of TID programs, the cardinal focus of such programs should be on the objective assessment of key and minimal requirements of the sport of rugby in potential players [5] utilising standardised test batteries. This implies that it is the key requirements of rugby which should provide a theoretical framework underpinning the selection of component variables for inclusion during test battery development [15]. However, in order to understand the key attributes, qualities or skills needed in rugby and, concomitantly, the variables to include in screening test batteries, knowledge of the physical demands of rugby is essential. This knowledge helps in understanding the locomotor and non-locomotor patterns common in rugby [16, 17] and, consequently, facilitates development of test batteries that replicates match demands. Furthermore, alternative approaches in understanding variables to include in test batteries involves establishing qualities, attributes or skills differentiating rugby players by levels of competition or related to match performance [18]. Identified qualities, attributes or skills with high discriminative ability and/or are associated with effective playing performance may then be incorporated in test batteries, as they potentially indicate important attributes required by rugby players.

Studies utilising Time Motion Analysis (TMA) and Global Positioning System (GPS) have shown that rugby is a dynamic, intermittent, and highly demanding physical sport [17, 19-29]. It is known that regardless of level of competition, rugby players spend 79% to 94% of match time in low-intensity activities (LIA), interrupted briefly by moderate-to-high intensity running or non-running activities such as striding, cruising, sprinting, static exertions (rucking, mauling, scrummaging), and tackling [17, 25-33]. It is these short, high-intensity activities (HIA) that are most crucial in rugby, possibly determining the outcome of rugby matches in terms which team win or lose a particular rugby match. Accordingly, understanding the key characteristics and skills needed to repeatedly perform these intense activities for the duration of a rugby match should have important implications in test battery design. Additionally, static exertions and power-based tasks such as tackling occur throughout the game of rugby and require high levels of upper-and-lower body muscular strength and power [17, 34]. As such, numerous studies have documented evidence of the relationship between these physiological characteristics and future career success or team selection [3, 34-38]. Therefore, it seems logical to include measurements of upper-and-lower body muscular strength and power in test batteries designed for screening potential rugby talent in TID programs given and also for general profiling of rugby players given the importance of these characteristics in rugby.

Literature has also shown that sprinting efforts over short and long distances are key movement patterns commonly observed in rugby for both forward and back players [25, 32, 33, 39-43]. Therefore, testing of speed is important and should be over varied distances reflecting the requirements for the different positions. With repeated efforts, both sprinting and static exertions require some degree of endurance considering 70 or 80 minutes of match play [17, 31, 44-46]. Thus, the ability to perform repeated HIA is essential and potentially important to screen for when identifying talent [47, 48]. Specifically, repeated sprinting ability (RSA) and repeated high-intensity exercise (RHIE) performance ability should be important components in test batteries [34, 47-51]. Smart et al [51] showed an association between speed and RSA with tries scored in a match, suggesting the importance of these characteristics in relation to match performance. Additionally, Gabbett [48] reported moderate to large effect size differences between the starters and non-starters rugby league players for speed, change of direction speed (CODS) and aerobic capacity, further illustrating the importance of these characteristics.

Pienaar et al [52] assembled a test battery measuring 21 anthropometric variables, eight (8) motor and physical abilities and six (6) games skills for identifying young South African rugby players. Also, test batteries utilised by Van Gent and Spamer [53] and Spamer and De la Port [54] for the same population had a similar multi-dimensionality. However, critical appraisal of these test batteries showed that the rationale for inclusion of the test items was seldom provided in the content of the articles and several variables were missing which would have given sufficient logical validity to the test batteries that are designed particularly for profiling anthropometric, physical, physiological abilities and rugby-specific skills among young players. Variably, the batteries excluded tests for tackling, reactive agility, RHIE performance ability, repeated effort ability (REA), (an)aerobic capacity, and lower-body muscular strength and power which probably emphasise the intermittency and physical nature of rugby. It is, therefore, imperative when developing test batteries for young adolescent rugby players to include test items that logically and comprehensively reflects the demand components of the game and has reliable, valid and feasible tests for the context it is to be implemented. Test batteries that are logically validated to the needs of the young rugby players containing also practically feasible tests are more likely to be relevant for use in screening or talent recruitment programs and to be implemented by the intended users such as coaches, strength and conditioning experts and sports scientists. Such test batteries can be consistently used to determine players' competency levels, TID, creating a profile of each individual athlete, tracking progress over time and also evaluating the effectiveness of interventions [12]. Therefore in an attempt to comprehensively understand the key physical, physiological and skill-based needs of young male adolescent rugby players between the ages of Under 16 and Under 19, based on shared consensus among rugby experts, this study evaluated the logical validity of the test variables included in a newly-developed test battery called the School Clinical Rugby Measure (SCRuM) and, further evaluated the practical feasibility of each corresponding test in the test battery in the Zimbabwean context. In the broader context of the large doctoral study in which this study was part of, the test battery was developed with the ultimate aim of determining anthropometric, physical or physiological characteristics and rugby-specific game skills discriminating young (U16-U19) Zimbabwean male rugby players by level of competition.

6.3 Material and methods

6.3.1 Test battery development

The present study was conducted as part of a large multi-phased study (Table 6-1). Briefly, Phase I entailed development of the first version of the SCRuM test battery through a three-part process (Table 6.1). The process was informed by literature recommendations for instrument or test battery development [55-58]. However, the actual selection of the candidate items and corresponding tests considered interplay of several factors such as:

i. The physical, motor or physiological characteristics and rugby-specific technical game skills identified to be commonly assessed in the literature.
ii. The tests frequently used for the assessment of each of the identified construct in rugby and other related intermittent sports such as rugby league. However, tests found specifically developed for rugby players were preferentially selected for inclusion over generic tests for the corresponding variable.
iii. The qualities, attributes or skills local rugby coaches perceived to be important in defining a good rugby player and are important for consideration during talent recruitment in TID programs.
iv. The tests known and frequently used by rugby coaches in the local context during training or for assessment of players.
v. The availability of acceptable psychometric or measurement properties (reliability, validity and responsiveness) for the test based on the Consensus-based Standards for the Selection of health Measurement Instruments (COSMIN) checklist.

vi. The level of evidence for the test based on "best evidence synthesis" of the psychometric properties based on the quality criteria for rating of measurement properties provided by Terwee et al [59].

The authors (MC, BSE, SO) formed the working group that selected the test items for the SCRuM test battery largely guided by the ultimate purpose of the test battery and the factors alluded above.

Table 6-1: Methodological stages used to develop and validate the SCRuM test battery

Phase	Part	Aim	Methodology
Phase 1	Part I	Determined what is known about the key requirements of rugby specifically targeting anthropometric, physical or physiological characteristics and rugby specific game skills in literature.	Narrative literature review
	Part II	Explored perceptions of rugby coaches on the key attributes or qualities and game skills needed in rugby and should be incorporated in test batteries for TID programs. This part also sought commonly used test(s) for the identified attributes and skills used in the local context	A qualitative study
	Part III	Determined frequently assessed physical or physiological characteristics and rugby-specific game skills and their corresponding tests in literature and evaluate the psychometric properties of each identified tests per construct [10, 11].	Systematic review
Phase 2	Part I	Determined face validity of the first version of SCRuM test battery.	Face validation study using key informants
	Part II	Determined the logical validity of the second version of the SCRuM test battery. Logical validity was assessed in two rounds, engendering the third and fourth version.	Logical validation study using rugby experts
	Part III	Assessed the practical feasibility of the test items in the fourth version of the SCRuM test battery, engendering the fifth version of the SCRuM test battery.	Cross-sectional descriptive study using local rugby coaches
Phase 3	Part I	Assessment of the test-retest reliability of the fifth version of the SCRuM test battery, engendering the sixth version if there are changes to the content of the fourth version.	Test-retest reliability study
	Part II	Assessment of the construct (discriminative) validity of the sixth version of the SCRuM test battery engendering the final version of the SCRuM test battery with tests able to discriminate young male rugby players by level of competition	Construct validation study

Appendix O shows the first version of the SCRuM test battery and the rationale for choosing each included test. Following development, the test battery was subsequently evaluated for face and logical validity and practical feasibility. This is the part described in this paper. For ease of understanding, the present study was separated into three parts (Part I, II, III) and describes the methods and results for each of these parts.

6.4 Part 1: Face validation of the test battery

Although face validity is not considered an active measure of validity, it yields subjective but important preliminary information on whether study instruments measure what they purport to measure [60]. For the present study, face validity was considered as the extent to which the SCRuM test battery appeared to have component variables measuring the following pre-selected domain constructs: anthropometric, physical or physiological and rugby-specific game skills. Moreover, each test was assessed considering the degree to which it "looked" to be measuring the corresponding variable [61]. The study targeted key informant coaches coaching first team male rugby players from schools in the "elite" Super Eight Schools Rugby League (SESRL) and "sub-elite" Co-Educational Schools Rugby League (CESRL [2] based in Harare, Zimbabwe. The SESRL and CESRL represent the most competitive domestic high school rugby leagues in the country. A researcher-developed questionnaire listed all the SCRuM variables, corresponding tests and details of the test procedure (Appendix P). Participants rated each test based on a Likert scale (*1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree*) depending on whether the test appeared to be measuring the corresponding variable. Arbitrarily, at least 50% of the respondents had to agree or strongly agree for a test to be considered as having face validity. The questionnaire also elicited qualitative comments for any test item judged 1, 2 and 3. Respondents also had to provide a comment on whether the test battery adequately reflected a compilation of anthropometric, physical or physiological characteristics and rugby-specific game skills. Ethical approval was obtained from the Human Research Ethics Committee at the University of Cape Town (ref: 016/2016) where the lead author is registered as an international doctoral student in the School of Health and Rehabilitation Sciences in the Division of Physiotherapy (Appendix D). In addition, ethical approval was subsequently sought and obtained from the Medical Research Council of Zimbabwe (ref: MRCZ/A/2070; Appendix Q), since the study was conducted in Zimbabwe. Identified rugby coaches provided written informed consent prior to data collection (Appendix R).

6.5 Results

Five (5) high school male coaches, with the median age of 45 years, volunteered to participate in the study Table 6-2. Overall, the coaches endorsed the face validity of the SCRuM test battery. However, four of the respondents felt that the multistage fitness test (MSFT) measuring maximal aerobic power was a "duplication" of the Yo-Yo intermittent recovery level I (Yo-Yo IRL1) test measuring PHIIRA/endurance.

Table 6-2: Face validation results of the newly-assembled SCRuM test battery (N=5)

SCRuM variable item	Corresponding test	Likert scale responses					Decision to include/exclude
		S. Disagree, *n*	Disagree, *n*	Neutral, *n*	Agree, *n*	S. Agree, *n*	Final Decision
Speed	5m, 10m, 20m, 40m speed test	0	0	0	0	5	Included
RSA	Rugby-specific repeated speed (RS^2) test	0	0	0	3	2	Included
REA	REA test	0	0	0	4	1	Included
RHIE performance	RHIE performance test	0	0	0	3	2	Included
PHIIRA/endurance	Yo-Yo intermittent recovery level 1 test	1	1	0	2	1	Included
Maximal aerobic power	Multistage fitness test	1	3	0	1	0	Excluded
Anaerobic capacity	Triple 120m shuttle test	1	0	0	3	1	Included
CODS/agility	L-run test	0	0	0	0	5	Included
LB muscular power	Vertical jump test	0	0	0	3	2	Included
LB muscular strength	One-repetition maximum back squat test	0	0	0	1	4	Included
UB muscular power	2-kg medicine ball chest throw test	0	0	0	2	3	Included
UB muscular strength	One-repetition maximum bench press	0	0	0	3	2	Included
UB muscular endurance	Flexed arm hang	0	0	0	5	0	Included
Abdominal endurance	60-seconds sit-up test	0	0	0	4	1	Included
Reactive agility	Reactive agility test	0	0	0	5	0	Included
Tackling	Tackling proficiency test	0	0	0	1	4	Included
Catching	Running and catching test	0	0	0	4	1	Included
Kicking	Kicking for distance test	0	1	0	4	0	Included
Passing for distance	Passing for distance test	0	0	0	2	3	Included
Passing for accuracy	Passing for accuracy test	0	0	0	2	3	Included

Anthropometric measures and body composition (skin folds) were omitted in the tables. All coaches agreed to strongly agree for inclusion for those variables; Repeated sprinting ability-RSA; PHIIRA-prolonged high intensity intermittent running ability; S.Disagre-Strongly Disagree; S.Agree-Strongly Agree; UB-Upper body; LB-Lower body; REA-repeated effort ability, n-number, CODS-change of direction speed

6.6 Part 2: Logical validity

After the preliminary face validation using coaches identified as key informants, the test battery was subjected to detailed evaluation of its content using rugby experts. Although the term content validity is commonly applied for questionnaires [62], in the context of performance measures the term addresses questions such as "how well a specific test measures what it intends to measure?" or "do the items included in the test cover the entirety of those relevant to assessing a particular skill outcome measure?" [13]. Terms such as logical or definitional validity have also been used interchangeably with content validity [58]. It appears, however, that logical validity is often applied for sports-based tests [8, 55, 63, 64]. For example, Rikli and Jones [55] described logical validity as the degree to which a test (or a test battery) reflects a defined domain of interest. According to Hendricks et al [8], the fundamental question describing logical validity of a rugby test is "does the test measure a relevant and important aspect of rugby?"

6.6.1 First round

This first round was designed to establish the logical validity of the 22 variables and their corresponding tests in the SCRuM test battery. The COSMIN checklist provided the definitional guideline for logical validity [61]. Logical validity was established through two rounds of expert consultations. Panellists assessed the relevance of SCRuM test battery items by age, gender and overall purpose of the test battery as per the COSMIN guidelines. The primary objective was to determine component items with acceptable Content Validity Index (CVI). Secondly, the study sought to identify characteristics and their corresponding tests missing in the SCRuM test battery but highly recommended for inclusion by at least half of the participating rugby experts.

International and local rugby experts participated in the study. International experts were selected based on being Professors or PhD holders having at least three publications on rugby. The recruitment of local experts was premised on identifying a representative sample of experts with at least 5 years of coaching or playing or directing or involved in rugby in Zimbabwe. A researcher-developed logical validation instrument was used for data collection (Appendix S). Experts rated the relevance of each SCRuM variable based on a Likert scale as follows: *1 = test not relevant, 2 = test somewhat relevant,* *3 = test quite relevant, 4 = test highly relevant* [65]. In addition, experts had to comment for test variables rated 1 or 2, recommend missing variables and corresponding test(s).

6.6.1.1 Procedure

This study was conducted between January and February 2018. Possible candidate names for international experts were obtained from an online document listing "top" 100 experts in sports science [66] and also from reference lists of two systematic reviews conducted by the lead author [10, 11]. This was done to determine the authors frequently publishing on physical characteristics and rugby-specific game skills. So, these two strategies provided the sampling frame for the international experts. However, the actual decision for the selection of international experts was based on consensus agreement among three authors (MC, DC and BSE) considering factors such as

i. *The availability of active and recent email address*

ii. *The availability of the expert on Research Gate (a research platform enabling us to evaluate expert publications, academic qualifications and biographs)*

iii. *The availability on social media platforms such as LinkedIn or Twitter (an additional invitational platform for experts when emails "bounce"), and*

iv. *The number of publications pertaining to rugby on PubMed or Google Scholar.*

Email addresses of selected experts were mainly obtained from journal articles and university webpages. In total, 43 international experts were identified and invited to participate via email. Experts were furnished with the online questionnaire through REDCap (a secure web application for building and managing online surveys). For the local experts, purposive sampling method was used for the recruitment, with participants assisting in identifying others (snowballing). In total, 20 local rugby experts were approached and those who agreed to participate signed the informed consent form (Appendix T).

6.6.1.2 Statistical analysis

Item-Content Validity Index (I-CVI) was computed for each test item as the number of experts giving a rating of either 3 or 4 divided by the total number of experts [67-69]. CVI is the most widely used quantitative approach for the content validation [58, 67]. The adopted cut-off for an acceptable I-CVI was >0.78 [68]. Each test item with I-CVI >0.78 was deemed relevant for inclusion in the test battery. The percentage agreement (the number of test items with an I-CVI of 1.00 divided by the total number of items validated in the test battery, expressed as a percentage) was also calculated to represent the proportion of test items experts deemed highly relevant. Scale level-Content Validity Index (S-CVI) was mathematically computed as an average of all I-CVIs [68]. This represented the overall logical validity of the SCRuM test battery. A second round of validation was needed when the S-CVI/Ave for the test battery was below the acceptable cut-off of 0.90 [68]. In addition, an index of inter-rater agreement adjusting for chance agreement [58] was calculated for each test item as indicated in Larsson et al [67].

6.7 Results

We invited 63 local and international experts of whom 20 (31.7%) agreed to participate. The eight international experts represented United Kingdom (5), South Africa (1), Australia (1) and New Zealand (1). The experts were either professors or PhD holders in human movement sciences, sports physiotherapy or medicine and with preferential interest in rugby. The length of experience ranged from 13 to 25 years mainly in lecturing and sport science research. Of the 12 local experts, they included two (2) sport scientists, senior rugby coaches, and former Zimbabwe national team rugby players, one (1) current Zimbabwe senior national team rugby player, former Zimbabwe national rugby team coach, former Zimbabwe national rugby team sports director, former Zimbabwe national Under-19 team manager, junior rugby sports director at a local school, and physiotherapist for the Zimbabwe national rugby team. Table 6-3 summarises the rating of each of the variables in the SCRuM test battery.

Table 6-3: Results for first part of the content validation study

SCRuM variable	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20
Speed	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	4	4	4	4	4
RSA	4	4	4	2	4	2	3	3	3	4	4	2	4	4	4	4	4	3	4	3
REA	2	4	2	2	4	4	4	3	1	4	4	2	4	4	4	3	4	3	3	4
RHIE	1	4	1	4	3	4	4	3	4	4	4	4	4	4	4	4	4	3	3	2
PHIIRA/Endurance	4	4	4	3	3	3	4	2	4	4	4	4	3	3	4	4	4	4	4	4
Anaerobic capacity	4	4	4	2	3	4	2	2	2	4	3	3	4	4	4	4	3	4	4	4
CODS/agility	4	4	4	4	4	2	3	3	4	4	4	4	3	4	4	3	3	4	4	3
LB muscular power	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	3	4	4
LB muscular strength	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	3	3	4
UB muscular strength	4	4	4	4	3	3	4	3	4	4	4	4	4	3	4	4	4	4	4	4
UB muscular power	4	4	4	3	4	3	4	3	4	4	4	4	4	4	3	4	4	3	3	3
UB muscular endur*	4	4	4	2	3	1	3	2	2	4	2	4	3	3	3	4	3	3	4	3
Abdominal endurance	2	4	2	2	3	3	2	1	1	4	2	1	3	4	3	4	3	3	3	3
Reactive agility	4	4	4	3	3	4	3	3	4	4	4	3	4	4	4	3	4	3	4	4
Tackling	4	4	4	4	4	4	4	2	4	4	4	3	4	4	4	4	4	3	4	4
Catching	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	3	4	4	3
Kicking	4	4	4	2	3	2	3	2	1	4	2	4	2	3	3	3	2	4	3	4
Passing for distance	4	4	4	2	4	2	3	2	1	4	2	4	2	4	3	3	2	4	4	4
Passing for accuracy	4	4	4	4	4	4	4	3	3	3	4	4	4	4	3	3	4	4	3	4
Height	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Weight	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Skin folds	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4

R=Rater; 1=not relevant, 2=somewhat relevant, 3=quite relevant, 4=highly relevant; Prolonged high intensity intermittent running ability=PHIIRA; Repeated sprinting ability=RSA; Repeated effort ability =REA; Repeated high intensity exercise performance= RHIE; Maximal aerobic power= MAP; Change of direction speed=CODS; LB=lower body; UB=upper body; *Upper body muscular endurance

The calculated I-CVIs and the corresponding modified kappa coefficient values for each test item in the SCRuM test battery are shown in Table 6-4. The calculated I-CVIs ranged from 0.6 to 1. Overall, the test battery achieved an S-CVI/Ave of 0.86. Ten variables had excellent kappa values (k=1). Hence, the percentage agreement for the SCRuM test battery was 43.5%. Five (5) variables were excluded and the reasons are shown in Table 6.4. Thematic analysis of the recommended attributes showed that "muscle flexibility" was highly recommended by 13 (65%) of the experts. However, Sit-and-Reach test was reported as the most commonly used test for the variable. The other attributes and skills recommended for inclusion were: defensive and offensive skills (n=2), balance (n=3), anticipatory or reaction skills (n=3), abdominal strength (n=2) and ball rucking (n=1).

Table 6-4: Item-content validity indices for the SCRuM test items

Scrum variables	Relevant (3 or 4)	Not relevant (1 or 2)	I-CVI	Kappa (k)	Interpretation	Rationale for exclusion
Speed	20	0	1	1	Validated	
RSA	17	3	0.85	0.85	Validated	
REA	15	5	0.75	0.75	Excluded	It mimics RHIE and is not as important as RHIE
RHIE	17	3	0.85	0.85	Validated	
Endurance/PHIIRA	19	1	0.95	0.95	Validated	
Anaerobic capacity	16	4	0.8	0.8	Validated	
CODS/Agility	19	1	0.95	0.95	Validated	
LB muscular power	20	0	1	1	Validated	
LB muscular strength	20	0	1	1	Validated	
UB muscular power	20	0	1	1	Validated	
UB muscular strength	20	0	1	1	Validated	
UB muscular endurance	15	5	0.75	0.75	Excluded	Not common and relevant in rugby, indirectly assessed by other variables
Abdominal endurance	12	8	0.6	0.6	Excluded	Not common and little evidence supporting its relevance in rugby
Reactive agility	20	0	1	1	Validated	
Tackling	19	1	0.95	0.95	Validated	
Passing for distance	13	7	0.65	0.65	Excluded	Not regarded as important as compared to passing for accuracy.
Passing for accuracy	20	0	1	1	Validated	
Catching	19	1	0.95	0.95	Validated	
Kicking for distance	13	7	0.65	0.65	Excluded	Position dependent

RHIE-repeated high intensity exercise; LB-lower body; UB-upper body; PHIIRA-prolonged high intensity intermittent running ability; CODS-change of direction speed; results for anthropometric variables are excluded from the table but were all validated for inclusion in the composition of the test battery

6.7.1 Second round

A second round was needed for the experts to review the findings for the first round. In addition, experts had to judge the relevance of muscle flexibility as a characteristic important for inclusion in the test battery, and report on the most commonly assessed muscle for flexibility. The experts had to give an overall impression on whether they agreed or disagreed that the test battery was sufficiently comprehensive in covering all relevant physical or physiological and rugby-specific game skills. Procedurally, this entailed sending or providing a summary of the results of the first round to experts via email or in person. Overall, the proportion of agreement among the experts was calculated as a measure of comprehensiveness of the SCRuM test battery. The relevance of inclusion for muscle flexibility was evaluated as previously described using the CVI calculation method.

6.8 Results

Out of the 20 experts invited to participate, three (3) international experts timeously responded. Additionally, six (6) local experts were available to participate in the study. Of the 18 variables, RSA was considered not essential for inclusion in the test battery. Experts felt that RSA was already incorporated in the RHIE test. There were also suggestions from three (3) experts for the removal of anaerobic capacity (measured by the Triple 120m shuttle test), since it could be indirectly assessed using the RHIE tests. Muscle flexibility had an I-CVI of 0.89 from eight (8) raters. According to the experts (n=7), the lower back and hamstring muscle flexibility is commonly assessed in rugby. Overall, all the rugby experts agreed on the comprehensiveness of the test battery in including a wide range of physical or physiological characteristics and rugby-specific skills.

6.9 Part 3: Practical feasibility

This study was conducted to establish the practical feasibility of conducting each of the tests in the logically-validated SCRuM test battery. Literature advocates for the development of test batteries that are feasible, reliable and valid [8, 13, 14, 70]. Feasibility concerns are multifaceted and include assessment of parameters such as equipment needed, cost of equipment, time, procedure, human resources needed, ease of scoring and interpreting test results, safety and duration of the test [8, 13, 14, 70].

6.9.1 Study design and participants

A cross-sectional descriptive study targeting rugby coaches from high schools and senior rugby clubs in Harare, Zimbabwe was conducted. Coaches were targeted because of their potential in applying the findings of this study in their work environment. For the identification of the rugby coaches, high schools in Harare were categorised into SESRL, CESRL, and IHSRL (Interscholastic High School Rugby Leagues). All the rugby coaches in the SESRL and CESRL were invited to participate by virtue of their schools participating in the reputable leagues. However, a random selection of the schools (n=48) was conducted for the identification of the coaches in the IHSRL. The league is composed of public and private amateur rugby schools which do not participate in the SESRL or CESRL. All the rugby coaches in the selected schools were then invited to participate. Additionally, senior rugby club coaches were approached on individual basis for possible participation in the study.

6.9.2 Instrument

A practical feasibility instrument was specifically designed for this study (Appendix U). Briefly, Section A elicited demographic data and rugby-related information of the coaches with regards to age, gender, high school or club coaching experience (years started coaching, rugby school team coaches, the league the school is in, any other coaching experience besides school or club rugby) and personal rugby experience (whether they have played rugby in their lifetime, and the level they played). Section B was the feasibility data scoring sheet requesting the coaches to rate the practical feasibility of the each test in the SCRuM test battery as follows: *0-not practically feasible, 1-somewhat feasible, 2-practically feasible*. The three main feasibility parameters evaluated included:

i. ***Test equipment issues***: evaluating type of equipment needed and cost of purchasing it.
ii. ***Test procedural issues:*** evaluating the ease of conducting the ideal procedure and the alternative procedure of the test, duration of test, human personnel needed, and easy of scoring and interpreting test results.
iii. ***Test acceptability issues:*** evaluating logical acceptability/perceived appropriateness, age-specificity, and safety concerns of the test.

6.9.3 Procedure

A total of 22 high-schools based in Harare, Zimbabwe were invited to participate. School rugby coaches in these schools willing to participate in the study were recruited. Male head coaches from five (5) senior professional rugby clubs were approached on individual basis and invited to participate in the study. Written informed consent was obtained from the participants (Appendix V). Upon agreeing to participate, the coaches were given the following study documents: the practical feasibility questionnaire and the SCRuM test battery informative document. The latter document had detailed information about each test in the test battery including information on every feasibility parameter from the type of equipment needed, estimated cost of purchasing the equipment, test procedural issues, anticipated duration and human resources needed, ways of scoring and interpreting test results, to information on test acceptability issues.

6.9.4 Statistical analysis

The 10 feasibility parameters were grouped into three categories based on perceived importance of each parameter:

i. ***High-Priority Feasibility Parameters (HPFPs):*** This included equipment needed, procedure of the test, possible modifications to the test or equipment, and cost analysis. These four (4) parameters were considered by the research team as the key determinants of practical feasibility of each test. Participants had to rate the feasibility of each test on the aforementioned four parameters based on: *0-not feasible, 1-somewhat feasible and 2-feasible*. The total weighted score for HPFPs was 32 (calculated as the maximum possible feasibility scores for HPFPs, which was 8, multiplied by an arbitrary weighted ratio of 4).

ii. ***Medium-Priority Feasibility Parameters (MPFPs):*** This included average duration, human resources needed, scoring and interpretation of test scores. These three (3) parameters were considered of moderate importance to practical feasibility. For each of these parameters, each test was rated based on: *0-not feasible, 1-somewhat feasible and 2-feasible*. The total weighted score for MPFPs was 12 (calculated as the maximum possible feasibility scores for

MPFPs, which is 6, multiplied by an arbitrary weighted ratio of 2 representing moderate importance).

iii. ***Low-Priority Feasibility Parameters (LPFPs):*** This included age-specificity, logical acceptability and safety. These three (3) parameters were considered of least concern with regards to practical feasibility. For each of these parameters, each test was rated as follows: *0-not feasible, 1-somewhat feasible and 2-feasible*. The total weighted score for LPFPs was 6 (calculated as the maximum possible feasibility scores for LPFPs, which is 6, multiplied by a weighted ratio of 1).

The maximum possible weighted total score for the each test item was 50. The calculated average score of each test represented the **Test-Feasibility Index (T-FI).** The T-FI scores were dichotomised for interpretation as high (≥35) and low. Tests with low T-FI warranted complete substitution from the test battery.

6.10 Results

Thirty (30) male junior rugby and senior rugby club coaches volunteered to participate in the study. The mean age of the coaches was 43.6 years (SD=4.49, age range=36-56). The total number of years coaching either school or club rugby ranged from 3 to 18 years for the coaches. Of the 17 tests in the SCRuM test battery, the majority (n=14) were perceived to be practically feasible to be conducted in the local setting (Table 6-5). Three tests, namely, reactive agility test (RAT), one-repetition maximum back squat (1-RM BS) and one-repetition maximum bench press (1-RM BP) had average T-FIs below >35. Specifically for the RAT, participants had concerns on the type of equipment needed and the cost of the equipment. For the 1-RM BP and 1-RM BS tests, feasibility concerns raised were mainly on equipment needed, cost of equipment, age-specificity of the tests and logical acceptability of the tests.

Table 6-5: Practical feasibility results of the SCRuM test battery (N=30)

Construct measured	Corresponding test	Average Feasibility Index Score (T-FI)	Interpretation
Speed	5m, 10m, 20m, 40m speed test	41.9	High practical feasibility
RHIE performance ability	RHIE test	36.5	High practical feasibility
PHIIRA/Endurance	Yo-yo intermittent recovery level 1 test	40.8	High practical feasibility
Anaerobic capacity	Triple 120m shuttle test	42.2	High practical feasibility
CODS/agility	L-run test	43.6	High practical feasibility
LB muscular power	Vertical Jump test	42.7	High practical feasibility
LB muscular strength	1-RM back squat test	22.6	**Low practical feasibility**
UB muscular strength	1-RM bench press test	23.0	**Low practical feasibility**
UB muscular power	2-kg medicine ball chest throw test	43.6	High practical feasibility
Muscle flexibility	Sit-and-reach test	48.1	High practical feasibility
Reactive agility	Reactive agility test	32.2	**Low practical feasibility**
Tackling	Tackling proficiency test	41.0	High practical feasibility
Passing-for-accuracy	Passing-for-accuracy test	40.1	High practical feasibility
Catching	Running and catching test	40.9	High practical feasibility

T-FI-Test feasibility index, RHIE-repeated high intensity exercise, CODS-change of direction speed, PHIIRA-prolonged high intensity intermittent running ability, 1RM=one repetition maximum, UB-upper-body; LB-lower body; anthropometry data for height, mass and skinfolds was considered practically feasible and was omitted from the table for those reasons

6.11 Discussion

The present study was conducted to evaluate the logical/content validity and the practical feasibility of each test item in the newly-designed SCRuM test battery developed for use in a large study to determine the anthropometric, physical, physiological and rugby-specific game skills discriminating young male adolescent rugby players by playing abilities or level of competition. Briefly, the test battery had been developed from information gathered through a narrative and systematic literature review [10, 11] combined with results from a qualitative study investigating the perceptions of local rugby coaches of the qualities important in rugby for young adolescent rugby players and the corresponding tests used for evaluation of these qualities. This study was therefore carried out to refine the first version of the SCRuM test battery by evaluating the relevance, comprehensiveness of the test items included in the test battery based on rugby experts perceptions and further ascertain the practical feasibility of conducting the various test items included in the test battery as judged by the local high school coaches likely to be intended users of the test battery.

The primary finding of this present study was that 17 out of the initial 23 variables were considered relevant for inclusion in the SCRuM test battery. This breadth highlights the diversity of physiological or physical qualities and game-specific skills needed by young rugby players between the ages of Under-16 to Under-20 irrespective of position. Another important secondary finding was that proposed tests for upper-and-lower body muscular strength and reactive agility that were included in the first version of the test battery were rather impractical for the Zimbabwean setting and for the age in consideration. These findings suggest need to substitute, or develop new practical feasible tests for the assessment of these important variables.

There was consensus among rugby experts for the inclusion of speed in the SCRuM test battery; a finding confirming the importance of speed in rugby regardless of players position. Speed, which is required for evading opponents, breaking through defensive lines, and scoring tries, has been found to discriminate rugby players of different levels of competition and playing abilities [30, 44, 71-73]. For example, elite junior rugby players were found to have superior sprinting abilities when compared to sub-elite players in a study comparing the physiological and anthropometric characteristics of junior elite and sub-elite rugby players [73]. There is also evidence showing that speed is the most frequently assessed physiological characteristic among rugby players based on findings from a recent systematic review [10]. Motion studies have revealed that rugby players cover varied distances (4m-46m) in a single bout of intense sprinting [25, 32, 33, 43]. This probably accounts for the assessment of speed for over 5m to 60m distances in literature [10]. In the present study, the included speed tests (5m, 10m, 20m, and 40m) were found to be relevant and practically feasible for the Zimbabwean setting and for the intended target population. The tests reflect the speed demands in match play for both the forward and backline players. Shorter sprints (<20m) which assess acceleration ability mainly characterise forwards running and the longer sprints (<40m) assessing maximal velocity commonly observed in game play mainly reflect running distances for the backline players [33, 44, 74].

HIA are an integral component of rugby [20, 25, 27, 75] and therefore the ability to perform RHIE should be an essential requirement. By assessing RHIE, coaches are informed about the level of physical fitness of players for rugby [50]. Concomitantly, the ability to recover quickly from HIA performances (anaerobic capacity) in preparation for a repeated episode should also be important to assess. This probably accounts for experts (n=3) recommending for the removal of anaerobic capacity as measured by the Triple 120m shuttle run test, since the variable was perceived to be indirectly assessed with the RHIE test. Furthermore, rugby experts selected RHIE for inclusion instead of RSA and REA. Tests for RSA and REA have been challenged for under-estimating the HIA characterising rugby matches [36, 49, 50, 76]. This probably explains the inclusion of specific RHIE tests for both the forward and backline players in the SCRuM test battery. The RHIE test for the forwards had scrummaging episodes as compared to the RHIE test for the backline players, reflecting the importance of the ability to engage in frequent scrummaging for the forward players. However, the proposed RHIE tests showed marginal Test-Feasibility Index (36.5) suggesting possible feasible concerns with the test. The major concerns highlighted included; human personnel needed, time needed to implement the test and age-specific issues considering the specified intensities and durations of RHIE bouts for the test. Rugby experts felt that tests for RHIE probably captured the intensities and durations for professional senior rugby players and may be demanding for the young adolescent high school-children playing rugby. There is need, therefore, to design or adapt the test for junior rugby players to improve the face validity and feasibility of the test among young Zimbabwean rugby players.

There was also consensus for the inclusion of CODS/agility in the test battery. Rugby involves large amounts of acceleration, deceleration and multi-directional running over short distances for all the players regardless of position [17, 39, 44]. This requires rugby players to have good agility without losing balance. Higher agility skills allow rugby players to play in a fast and efficient manner [77]. Therefore, CODS/agility has been reported to be an important variable for rugby players to possess [4, 34, 73, 78-80]. This importance is also evidenced by the frequency of assessment of CODS/agility in rugby players by coaches and sports scientists [10, 81]. In the present study, the proposed test for CODS/agility was found to be relevant and practically feasible for implementation in the Zimbabwean setting. However, the procedural movements of the L-run test were perceived to be “generic” and “mentally rehearseable” leading to better performances. This does not mimic field play, which is characterised largely by unplanned movement patterns [56, 82]. Possibly, it is for this reason that the experts agreed for the inclusion of reactive agility in the test battery. Oorschot et al [11] found that reactive agility was one of the most commonly investigated skill in rugby. In addition, Gabbett et al [18] demonstrated that reactive agility successfully discriminated first grade from second grade rugby players, further suggesting the importance of reactive agility in rugby. However, in the present study, the proposed test for reactive agility had a low practical feasibility index (T-FI=32.2), indicating possible feasibility challenges with the execution of the test in the Zimbabwean setting. The major areas of concern reported included the equipment needed and the cost of purchasing the equipment. Considering the constraints associated with the assessment of reactive agility, Turner et al [56] recommended use of CODS/agility tests alone for the assessment of agility in soccer players. However, reactive agility seems to be an important variable in rugby as compared to soccer because of the nature of the sport which requires multiple changes of direction in response to stimuli. There is need to incorporate both tests of change of direction speed and reactive agility in protocol development, since episodes of (un)anticipated agile manoeuvres both occur in match play [79].

Nonetheless, there is need for development of new practically feasible tests for the assessment of perceptual or decision-making aspects of agility in young rugby players.

There was perfect agreement among the experts for inclusion of anthropometric assessments (height, mass and skinfold thickness), upper-and-lower muscular power and strength, and muscular flexibility in the test battery. These findings suggest to the importance of these variables in rugby considering the dynamic and physical nature of the sport. Since acquiring professional status in 1995, rugby has grown into a quicker, more dynamic sport with greater emphasis on well-developed physical characteristics of players [81, 83-85]. Rugby players are subjected to frequent and powerful contact situations such as scrummaging, tackling, mauling and rucking [84, 85] which require body mass, muscle flexibility, strength and power. Muscle flexibility optimises eccentric and concentric contraction of the muscle ensuring efficient generation of strength. Leg strength facilitates increased leg drive which assists in sprinting, scrummaging, lifting, and tackling [34]. In addition, muscular strength and power has been reported to reduce the risk of injuries [72]. Performance of game tasks such as kicking, jumping, and lifting also require muscular strength and power generation abilities. Successful teams in international rugby are reported to have had the heaviest and tallest players [30, 86, 87]. Contemporary elite rugby players are known to be physically imposing (bigger and stronger) compared to players of two decades ago [87]. Gabbett [38] found that body mass was an important determinant of selection into a rugby team. Measures of upper-and lower body muscular strength and power were found to discriminate rugby players by level of competition [3, 34, 80]. However, in the present study, proposed tests for lower and upper body strength had low practical feasibility mainly because of the weightlifting restrictions imposed for young high school athletes in the country. Coaches had concerns on a number of feasibility parameters such as the type of equipment needed, the cost of the equipment, safety concerns, and age-specificity of the test with regards to these weightlifting tests. Therefore, there is need to incorporate new tests in the SCRuM test battery for assessment of lower and upper body strength among young rugby players in the Zimbabwean setting.

There was consensus among rugby experts for the inclusion of measures for passing, catching and tackling in the SCRuM test battery. However, measures for kicking were excluded on the basis for being position dependent. These findings suggest to the importance of accuracy in passing, running and catching ability and tackling in the sport of rugby, warranting the inclusion of these skills in screening test batteries. Time motion analysis (TMA) studies identified passing and tackling as key discrete movement activities commonly observed in match play [17, 26, 39]. This is because rugby is a running, passing, catching game with physical collisions such as tackles occurring throughout the entire match [17, 88-90].

6.11.1 Limitations

The study findings should be interpreted cognisant of number of limitations. The approach used for face and logical validation of the test battery can be criticised due to its potential for subjective and cognitive bias from the experts thereby influencing the validity of the results. However, attempts were made to draw experts from various countries for the different experiences. For the present study, 20 international and local rugby experts were used for this study. Nevertheless, it is possible that the content of the SCRuM test battery could have differed if different experts had been chosen. Achieving appropriate sample size and retaining experts in subsequent rounds was problematic with this study. Of the 63 experts invited, 20 and 9 participants participated in the first and second round, respectively. Therefore, the results reflect the opinions of experts who timeously responded and were willing to participate in the study. Nonetheless, all the experts were recruited based on expertise in the sport of rugby working in various capacities. In addition, literature is controversial on the ideal number of content experts needed in a validation study, but suggestions point between 3 and 10 [68]. This potentially suggests that the sample sizes for the first and second round of the validation may have been appropriate.

Another limitation of the present study was that experts judged the relevance of performance measures for inclusion in the SCRuM test battery based only on anthropometric, physiological characteristics and rugby specific game skills. Due to the complexity of the sport, there are however several other factors, for example, sociological, psychological or perceptual-cognitive skills such as decision making ability, anticipation, tactical awareness which may influence playing performance [72] and may be important to include in test batteries for distinguishing young rugby players.

Feasibility study results reflect the opinions and impressions of local rugby coaches used in this particular study considering the contextual resources available at the various schools in Harare, Zimbabwe that were selected. The results could have differed if other schools had been selected or if coaches with different coaching experiences had been used. The coaches used were also coaching at different levels of competition. This accounts for the results on practical feasibility for the upper-and-lower body muscular strength, since they are weight-lifting restrictions in the country depending on the age of the rugby players. U16 rugby players are not allowed to weight-lift as compared to the senior U-19 first team rugby players. In addition, the subjective nature of the data gathered may cover major practical feasibility issues which can become apparent during the implementation phase of the study. Therefore, there was need to assess other focus areas of feasibility besides practicality and acceptability issues. Feasibility of the SCRuM test battery could have been assessed in terms of demand (by actually documenting the use of the test battery by coaches in local context) or implementation (the extent, likelihood, and manner in which the SCRuM test battery is fully implemented as planned and proposed) [91]. However, this was not practical given the time limits this study had.

6.12 Conclusion

Rugby is a highly demanding physical and skill-based sport [92]. This is reflected in the component items included as relevant in the SCRuM test battery for profiling young male rugby players which covers a wide range of physical or physiological qualities and skills. Results from face and logical validity studies revealed that the following variables were relevant to be included in the SCRuM test battery: anthropometric qualities (weight, height and skin fold measures), physiological characteristics (speed, RHIE performance ability, PHIIRA/endurance, CODS/agility, anaerobic capacity, upper and lower-body muscular power and strength, muscular flexibility), and rugby-specific game skills (reactive agility, passing for accuracy, tackling proficiency, and catching). The present findings could inform coaches and sports scientists on the relevant attributes, qualities and skills to assess among potential rugby talent. Most of the tests except for upper-and-lower muscular strength and reactive agility were perceived to be practical feasibility to be conducted in Zimbabwean setting. Therefore, there is need to incorporate new tests in the SCRuM test battery for assessment of lower-and-upper body strength and reactive agility in the Zimbabwean setting.

6.13 References

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7 CHAPTER 7: RELIABILITY STUDY

7.1 Introduction

This chapter constituting the first part of Phase III presents the broad and specific objectives of the preliminary study conducted to establish the reliability of each of the test items in the fifth version of the SCRuM test battery. The chapter also describes the methods followed for the conduction of the study, results and discussion of key findings.

7.2 Broad objective of the study

Following development of the first version of the SCRuM test battery and subsequent evaluation of face validity, logical validity and practical feasibility of the component test items, the broad objective of this study was:

i. To establish evidence on the absolute and relative test-retest reliability of each of the component test items in the fifth version of the SCRuM test battery among a sample of young male adolescent players playing schoolboy rugby in the SESRL.

7.2.1 Specific objectives of the study

The specific objectives of the preliminary study were:

1. To identify test items in the SCRuM test battery with an acceptable coefficient of variation (CV <10%) as a measure of absolute reliability between repeated measures among a sample of elite U16 and U19 male adolescent rugby players playing in the SESRL.
2. To determine test items in the SCRuM test battery with a high Intraclass Correlation Coefficient (ICC) of above 0.70 as a measure of relative reliability between test-retest assessments using male adolescents playing competitive rugby in the SESRL for the U16 age category and U19 age category.

7.3 Methodology

7.3.1 Study design, participants and research setting

The study was conducted as test-retest reliability study to establish the absolute and relative reliability of each candidate item in the fifth version of the SCRuM test battery. The target population was elite U16 and U19 male adolescent players playing competitive rugby. Derived from tables in Walter et al [1] study, the estimated sample size (k) per age-category (either U16 or U19) was 18 participants computed utilising the following parameters for two (2) replicate measures: H_0: p_0 (minimally acceptable level of reliability) =0.7, H_1: p_1=0.9 (maximum expected value of reliability), beta (β) =0.2, alpha (α) =0.05. However, due to the large number of items in the SCRuM test battery, nature of the test-retest study design involving repeated measures, and the fact that data collection was conducted during the SESRL competitive season, over-sampling was done to counter for possible sample attrition from refusals to participate, withdrawals, school or training absenteeism, residual fatigue, study fatigue, ill-health and injuries.

As shown in Figure 7-1 below, one hundred and four (104) participants, representing all male adolescent rugby players training with the U16 (n=45) and U19 (n=59) first teams, were invited to participate in the study. The participants were derived from one of the schools based in Harare, Zimbabwe playing high school rugby in the prestigious SESRL. The school was purposively-selected since there were the defending champions in the SESRL and had won the SESRL three times in the last five years. Of the 104 invited, 88 (84.6%) obtained written informed consent from parents or guardians and were willing to participate in the study. However, a total of 82 male adolescent rugby players regardless of age category completed all the anthropometrical and test performances during the test-retest reliability study. The reasons for the drop-outs at each stage of participant recruitment are shown on Figure 7-1.

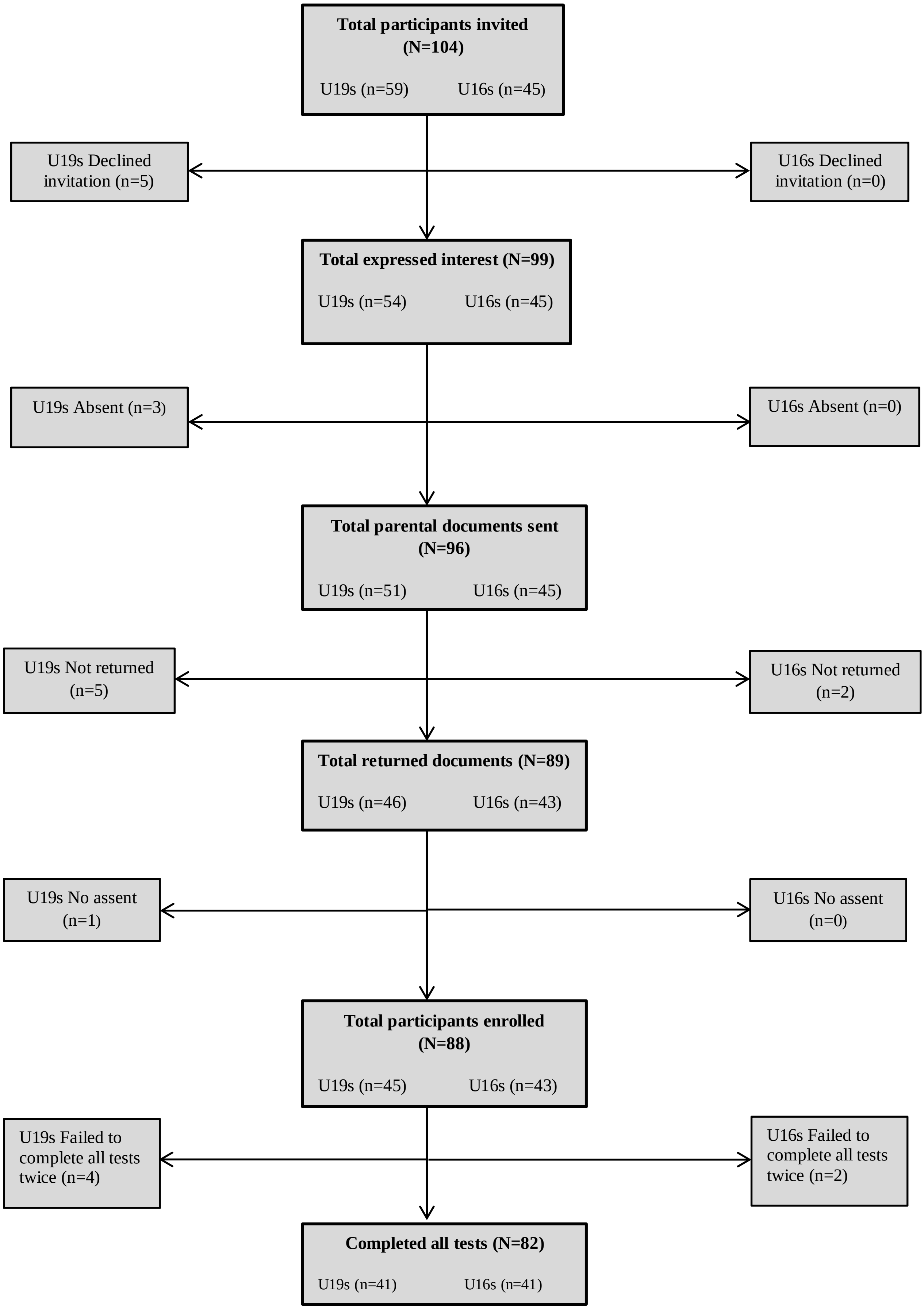


Figure 7-1: Flow chart for participants

7.3.2 Institutional permissions and ethical approval

Permissions to approach participants were sequentially obtained from the Ministry of Primary and Secondary Education (Appendix W), Harare Province Educational Director Office (Appendix X), headmaster (Appendix Y), sports director, and U16 and U19 rugby team head coaches. After obtaining ethical approvals from relevant committees, the research team approached all male adolescent rugby players playing first team U16 and U19 rugby at the selected school during one pre-season training session and personally invited them to participate. Verbal explanations of study purpose, test procedures, benefits and experimental risks were provided to participants. Those willing to participate were given information letters (Appendix Z) with study details and were sent home with parental documents which included the Adolescent Medical Health Questionnaire (AMHQ) (Appendix AA), parental information letters and informed consent forms (Appendix AB).

The AMHQ was designed to capture past medical and sports injury-related history of the participant from parents/guardians to inform on the possibility of athlete participation in the study or factors precluding participation. Parental information letters detailed the study purpose, experimental procedures and risks involved. Signed informed consents had to be returned directly to the primary investigator or to the respective head coaches at the end of seven days. Constant reminders were given to the participating students during training to return the parental documents. After that, written informed assents (Appendix Z) were then obtained from eligible participants whose parental informed consent forms had returned signed.

7.3.3 Procedure

7.3.3.1 Outline of annual rugby activities

Table 7-1 below shows an outline of annual rugby activities at the selected school and the timing of the SCRuM-related activities. Schoolboy rugby is a winter sport played during the second term of the school calendar from May to September for 15 or 16 weeks. However, intense preparations begin during the pre-season period from March to April of every year. The pre-season period is characterised by player mobilisation and recruitment, pre-season training and early conditioning, friendly inter-scholastic rugby matches, international and regional tours, and participation in the annual national youth rugby festival called the Dairiboard Zimbabwe Schools Rugby Festival (DZSRF). All these events are in preparation for the commencement of the SESRL league in May.

Table 7-1: Outline of rugby activities

Stage of the season	Period	Main Rugby Activities	SCRuM Activities
Off-season	Sept-Feb	Rest	
		Continued individual trainings	
Pre-season	Mar-Apr	Player mobilisation and recruitment	
		Player profiling	
		General preparation and conditioning	
		Pre-season friendly matches	
		Regional/International rugby tours	School permissions
		Zimbabwe School Rugby Festival	U19 1st Familiarisation
Early season	May-June	Continued team training	U19 2nd Familiarisation
		Strength and conditioning work	U19 Test assessment
		Commencement of the SESRL	U19 Re-test assessment
Mid-season	June-July	Continued team training	U16 1st Familiarisation
		Continued SESRL matches	U16 2nd Familiarisation
Late season	July-Sept	Continued team training	U16 Test assessment
		Continued SESRL	U16 Re-test assessment
		End of season	

Sept-September, Feb-February, Mar-March, Apr-April, Aug-August, 1st-First familiarisation session; 2nd-Second familiarisation session

7.3.3.2 Training and match sessions

Both U16 and U19 male adolescent rugby players had five training sessions per week from Monday to Friday, emphasising various aspects of game technique and skills, tactics, and physical training, speed training, aerobic conditioning, and simulated match games. Each training session lasted approximately three hours (14:00hrs-17:00hrs) for U19 players and two hours (14.00hrs-16.00hrs) for U16s. However, U19 male rugby players were allowed supervised or unsupervised training session per week emphasising resistance training in the gymnasium before commencement of regular training. The gymnasium sessions were conducted every Wednesday between 12.00 to 14.00pm. Inter-scholastic SESRL competitive matches were scheduled for Saturdays. The Sundays were designated as resting days for the participating schoolchildren.

7.3.3.3 Data collection approach

To establish the reliability of each SCRuM test items, a pragmatic "in-season" approach previously used by Enright et al [2] in youth elite soccer players was adopted. Specifically, we wanted to understand the reliability of SCRuM tests when test-retest assessments were scheduled during training days without disturbing the weekly training schedule, academic-related activities, and competitive match days. We had to adopt an approach likely to get approval from the coaching staff given the multitude of the tests to be performed and nature of the study design of repeated measures. The repeated measure design required all participants to perform the SCRuM test items on two separate occasions at the same time and day. To maximise retention rate and favour maximal performance, participants had to be tested in their familiar school environment.

7.3.3.3.1 Familiarisation

Two (2) familiarisation sessions for each age category were conducted separately for field-based and gym-based assessments to ensure sufficient exposure of study participants to the SCRuM test items before the first testing day (Table 7-1). On the second session, eligible participants would also complete a brief questionnaire soliciting demographic and rugby-related information. Data sought included *date of birth*, *years of playing competitive rugby*, *regular* and *alternative positions*, and the *current playing status in the team (starter vs. non-starter)*. This information had to be confirmed by the respective coaches. At the end of familiarisation sessions, dates for commencement of main study testing were agreed upon between the primary investigator and rugby coaches.

7.3.3.3.2 Testing

Participant testing commenced in the third week from the inception of the SESRL (Table 7-2). This approach ensured that participants had gained match physical fitness and were near peak performance [3, 4]. All testing was conducted during training sessions by trained research assistants used during the familiarisation sessions. On any day of testing, participants would complete the modified Physical Activity Readiness Questionnaire (PAR-Q) (Appendix AC) and their medical history noted from the AHMQ previously completed by the parents/guardians. Participants with self-reported injuries, illness or any other health-related condition reported by parents precluding participation in physical activity would be excluded [5]. Subsequently, eligible participants would complete standardised warm-up procedures before testing. The research assistant would then demonstrate the test to be performed and participants were allowed three (3) sub-maximal practice trials of each test before the experimental trial. The order of testing was as indicated in Table 7-2. A recovery period of 10minutes would be allowed between tests to minimise the fatigue-induced effects.

Table 7-2: Order of the SCRuM tests

*Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Under 19 1st and 2nd SCRuM test battery familiarisation sessions							
Week 1	Body mass Height 7 Skin folds Sitting height	Yo-Yo 2kg MBCT	1RM BP WSLG 1RM BS VJ	Speed SR L-run	RHIE Push Up	Match	Rest
Week 2	Body mass Height 7 Skin folds Sitting height	Yo-Yo 2kg MBCT	1RM BP WSLG 1RM BS VJ	Speed SR L-run	RHIE Push Up	Match	Rest
Week 3	Tackling	Passing		Catching		Match	Rest
Week 4	Tackling	Passing		Catching		Match	Rest
Under 16 1st and 2nd SCRuM test battery familiarisation sessions							
ˡWeek 10	Body mass Height 7 Skin folds Sitting height	Yo-Yo 2kg MBCT	VJ WSLG	Speed SR L-run	Push Up	Match	Rest
Week 11	Body mass Height 7 Skin folds Sitting height	Yo-Yo 2kg MBCT	VJ WSLG	Speed SR L-run	Push Up	Match	Rest
Week 12	Tackling	Passing		Catching		Match	Rest
Week 13	Tackling	Passing		Catching		Match	Rest

*represents the time the testing commenced which was exactly 3 weeks after the inception of the SESRL. Yo-Yo=Yo-Yo Intermittent Recovery Level 1 Test; 2kg MBCT=2kg medicine ball chest throw tests; 1RM BP=One repetition maximum bench press test; 1RM BS=One repetition maximum back squat test; WSLG=Wall Sit Leg Strength test; VJ=Vertical Jump test; SR-Sit-and-Reach test; Push Up=60s push up test; RHIE=Repeated High Intensity Exercise Performance Ability test; Match=Represents competitive match; 7 skin folds=biceps, triceps, subscapular, suprailiac, abdomen, thigh, and calf measures. Tackling=Tackling proficiency test; Passing=Passing ability and passing for accuracy for 7m test; Catching=Running and Catching Ability test. ˡ represented the time elite U16 were started on the SCRuM measurements from week 1. Weeks 5-9 were filled with other SCRuM activities including U16 familiarisation sessions and other measurements on other participating school teams as shall be seen in the subsequent chapter.

The re-test assessments for each SCRuM test item were conducted exactly after seven days approximately at the same time for each participant. The order of testing was in consultation with the coaches and sensitive to the moral responsibility of not wanting to disturb school-related academic and rugby-related training activities. During field testing, coaches were willing to release at most two players (one forward and one backline) from training for testing at any given time except on Tuesdays when the Yo-Yo intermittent recovery level 1 (Yo-Yo IRT L1) tests were conducted. Furthermore, to minimise fatigue interference, the most physically demanding dynamic running tests such as the Yo-Yo IRT L1 and the repeated high-intensity exercise (RHIE) test were interspersed by 48 hours.

Two (2) research assistants conducted all the SCRuM tests, except for the measurement of skinfolds and evaluation of participant performance on game-specific skills. Both had extensive experience in sports science research involving physical assessments. The latter tests were conducted by purposively-recruited subject experts in anthropometry (anthropometrist) and rugby (rugby coach). Each research assistant assessed the same athlete all the time. Testing occurred on a natural grass pitch for field tests and school gymnasium for strength and power based tests with participants requested to wear the same clothing all the time. The mean air temperature around testing days was $27\pm1.8^{\circ}C$. The research team provided similar verbal encouragement to all participants during all test performances. Test results were withheld from the participating athletes to avoid influencing re-test performances. Additionally, participants were unaware of the seven-day interval for the re-test assessments. Participants were advised to maintain normal diet, adequate hydration and avoid taking ergogenic aids including caffeine during the data collection period [6].

7.3.4 The SCRuM test battery

The SCRuM test battery was composed of (i) anthropometric variables (height, sitting height, body mass, seven skinfold measurements), (ii) physiological characteristics (speed, agility, upper-and-lower muscular strength and power, prolonged high-intensity intermittent running ability, muscle flexibility and repeated high-intensity exercise performance ability) and (iii) rugby-specific game skills (tackling proficiency, passing ability, passing-for-accuracy, and running-and-catching ability). However, only

U19 rugby players performed one-repetition maximum bench press (1-RM BP) and back squat (1-RM BS) tests because of regular exposure to resistance training compared to U16s. Instead, 60-s push-up and wall sit leg strength (WSLS) tests were incorporated into the SCRuM for group comparisons between U16 and U19 on upper-and-lower limb muscular strength, respectively. Inclusion of 60-s push-up test was based on recent findings of a systematic review highlighting common usage of the test for assessment of upper-body muscular strength in junior RU players [7]. The WSLS test is commonly used in training for estimating lower-extremity muscular strength or endurance for adolescent athletes in the local context [8].

7.3.4.1 The composition of SCRuM test battery

7.3.4.1.1 Height (cm)

Height was measured using a portable stadiometer (Seca Model 213, Hamburg Germany). ***Test procedure:*** Participants wore shorts and rugby training shirts. Participants were instructed to stand on the base of the stadiometer with the feet placed together, arms hanging by the sides and looking directly forward. The heels, buttocks, upper back, and head had to touch the stadiometer. The testing procedure involved lowering the stadiometer to the top of the participant's head and noting the height of the participant to the nearest 0.1cm. Giving 30 seconds "rest", the participants were measured again using the same procedure for the second measurement. ***Recording***: The mean of the two measurements was recorded.

7.3.4.1.2 Body mass (kg)

Body mass was measured to the nearest 0.1kg using calibrated Seca 813 high capacity digital flat scale. ***Test procedure***: The participant would stand on the scale with no movement allowed and arms hanging by the sides of the body wearing light clothing (shorts and rugby training shirt) with no shoes or socks. After the first reading, 30 seconds of "rest" were allowed and participants were measured again for the second reading. ***Recording:*** The mean of the two measures was recorded as participant body mass.

7.3.4.1.3 Skinfold measurements (mm)

The sum of seven site skinfolds (biceps, triceps, subscapular, suprailiac, abdominal, thigh and calf) was determined using calibrated Lange skinfold callipers. ***Test procedure:*** The same researcher performed all the skinfold measurements. The order of the testing followed was: biceps, triceps, subscapular, suprailiac, abdomen, thigh and calf. Participants were measured on the right side of the body. Participants would stand in the anatomical position with shirt removed. The research assistant would identify a landmark point using a tape measure and mark with a fine point felt tip pen. The specific positioning for taking the skinfold measurement of each site was in accordance with procedures described by Norton et al [9]. However, the general procedure involved gently and firmly "pinching" the skin and the subcutaneous fat between the thumb, forefinger and middle finger. The researcher would then open the skinfold calliper and measure the skinfold approximately 1cm below the finger and 1cm deep into the skinfold. The researcher would only release the calliper from the skinfold after obtaining the skinfold measurement. ***Recording:*** Two measurements per site were measured and had to agree within 1 millimetre otherwise subsequent measurements had to be taken until all values were within 1 millimetre.

7.3.4.1.4 Sitting height (cm)

Test procedure: The participants sat on a chair with hands resting on thighs. Minimal clothing was allowed. The research assistant would push the stadiometer down to vertex of head and recorded measurement to nearest 0.1 cm. The participant would stand up and re-measured again after 30 seconds. ***Recording:*** Sitting height represented stature height minus chair height. Age at peak height velocity (APHV) was deduced from the equation of Mirwald et al [10] given as: -9.326 + (0.0002708 x [leg length x sitting height]) – (0.001663 x [age x leg length]) + (0.007216 x [age x sitting height]) + 0.02292 x [weight/height]. An age at PHV prediction equation was used to assess maturation. The prediction equation has a 95% confidence interval for boys of ±1 year [10] and its relationship with skeletal age has been shown to be strong (r=0.83) [10, 11] suggesting better predictive validity for biological maturity. It should be noted that the Mirwald equation was determined in Canadian children and the applicability of this equation to a Zimbabwean population still remains unknown.

However, its level of accuracy for predicting biological maturity is sufficient for adolescence to be assigned a maturational classification. The maturity offset was determined by subtracting age at PHV from chronological age [10].

7.3.4.1.5 Speed tests (5-m, 10-m, 20-m, 40-m)

Warm-up procedure: A pre-test warm procedure supervised by the research assistant was conducted first for 2 minutes, including shoulder-arm stretches, trunk rotation stretches with hands on the waist, bilateral quadriceps femoris stretches in standing, toes-touch stretching and jogging. The starting procedure would be demonstrated by the research assistant and the participants allowed pre-test practice trials until the player is ready and has understood the procedure. ***Test procedure:*** The participants ran the 5m distance first, followed by the 10m, 20m and finished the sprint test on the 40m speed test (Figure 7-2). Participants would start from a stationary position, with one foot in front of the other. The front foot started precisely 50cm behind the starting line. The players would set off in their own time and run maximally through the specified distance [6]. The criteria used to determine the completion of the sprinting segment was the first body part to cross the finish line [12]. Two test trials were run for each distance and the better of the two was recorded for each distance. Each trial was separated by a 3-minute rest as recommended by Darrall-Jones et al [6]. The first research assistant at the starting line was judging if the start was valid and the second recorded the time taken. All the test trials with a false start were repeated. Markers were left on the pitch to ensure for identical placement of cones between sessions. ***Instrument and recording:*** All the times were recorded with a hand-held digital stopwatch as recommended from literature [13-15]. The JUNSD digital stopwatch (model JS-306) was used.

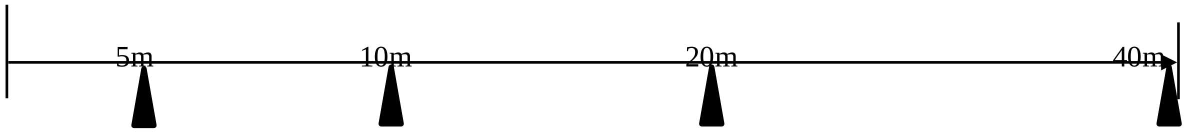


Figure 7-2: Linear speed tests

7.3.4.1.6 Modified L-run agility test (sec)

The test was conducted as previously described in literature by Gabbett et al [16] with minor modifications to mimic match play (Figure 7-3). ***Warm-up procedure***: A pre-test warm procedure was conducted first for 2 minutes, including shoulder-arm stretches, trunk rotation stretches with hands on the waist, bilateral quadriceps femoris stretches in standing, toes-touch stretching and jogging. The procedure would be demonstrated by the research assistant and participants were allowed pre-test practice trials until the player understood the procedure. ***Test procedure:*** Three cones were placed 5m apart from each other to represent an 'L' shape (Figure 7.3). For the modification, players would start on line 1 which was 1m away from the first cone lying in a prone position (chest down with the head on the 1m line) mimicking a rugby player coming from a physical collision, ruck or maul. At the first cone and on line 2, a rugby ball was placed and participants were instructed to get up on "GO" command and pick up the rugby ball and run as quickly as possible along the 5m distance, turn left, run forward in between the cones, turn 180 degrees, run straight to finish and score a "try" or drop the ball at the 1m line. ***Instrument and recording:*** Hand-held stopwatches were used to record the time from the start to the finish when the ball was dropped on the 1m line. Two trials were done and the best count was recorded. Additional trials were given when the participants failed to grab the rugby ball at the first cone, failed to execute the zigzag between the cones or droping the ball at the 1m line or the research assistant adjudicates that the prone lying at the start of the L-run agility test was not perfect.

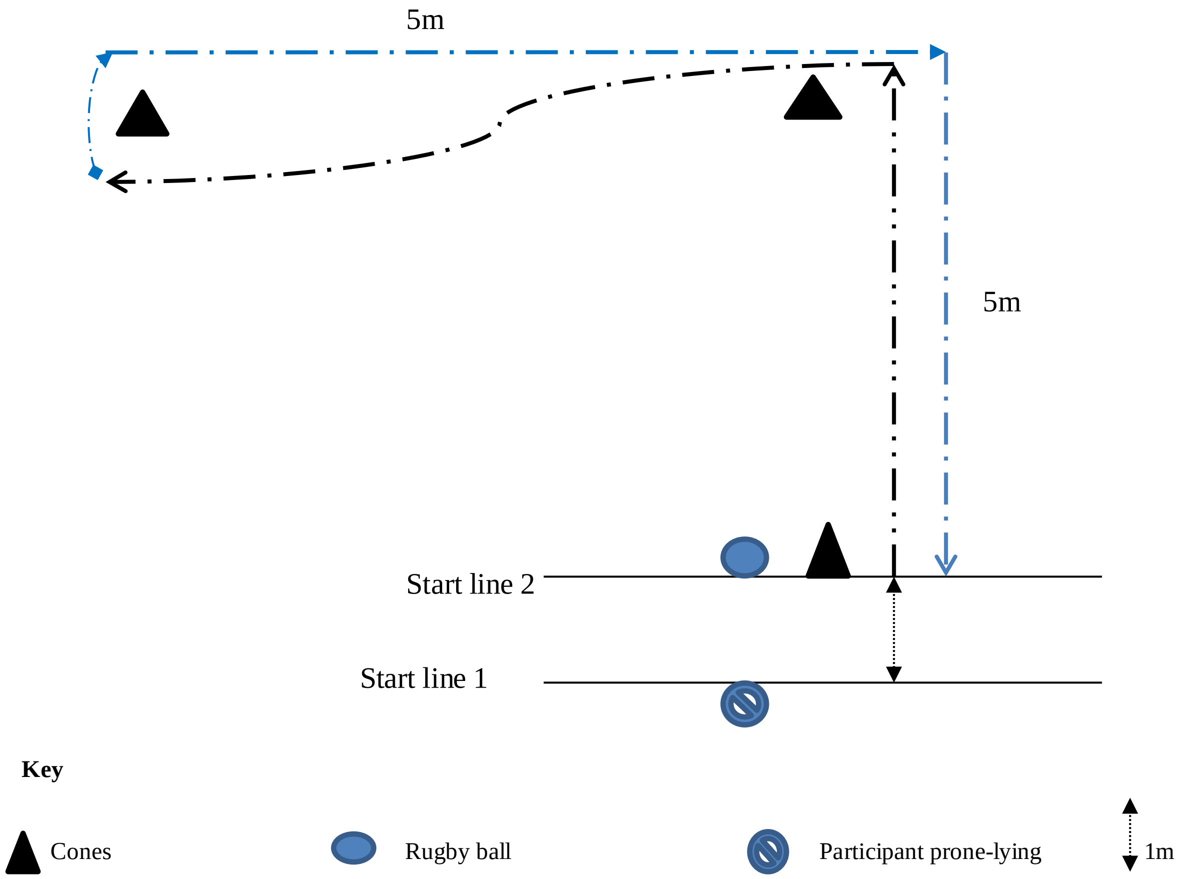


Figure 7-3: Protocol for the modified L-run agility test

7.3.4.1.7 Vertical jump (VJ) test (cm)

Warm-up procedure: Participant performed the VJ test barefooted for assessment of lower-body muscular power. A warm up procedure as explained for the sprint and agility tests were conducted first. The research assistant would demonstrate the testing procedure and participants allowed to practice with a maximum of three (3) practice trials. ***Test procedure:*** Players stood with fleet flat, shoulder width, on the ground, with the wall sideward to their dominant side. Participants were instructed to extend the upper-limb and mark the highest possible point with the chalk [17]. Then, the players were instructed to crouch deeply, close to 90 degrees of active knee flexion, while keeping the feet flat on the ground and spring upward as high as possible and mark the highest point possible on the wall. The research assistant would draw a small line with a ruler on top of the dot made by the chalk representing the maximum height reached. For the second trial, they had to hold a new full-length chalk between the tips of the index and middle fingers. Thirty (30) seconds of rest were provided in between the 2 trials. ***Instrument and recording:*** The best count was recorded in cm using a tape measure. If the player fell down during the procedure, the trial was re-done and if the crouching was too shallow the trial was stopped and re-done.

7.3.4.1.8 Sit-and-reach (SR) test (cm)

Warm- up procedure: Participant performed the SR test barefooted for muscle flexibility. A warm up procedure as explained for the previous tests was conducted first. The research assistant would demonstrate the testing procedure (Figure 7-4) and participants allowed to practice with a maximum of three (3) practice trials. ***Test procedure:*** Participants sat on the ground, knees extended, and soles of the feet contacting the rigid sit-and-reach box. Each subject would be asked to stretch as far forward as possible with stacked hands and to hold that position for one second. They were encouraged to go as far along as they can with the hands together and keep knees straight throughout. Each player was allowed 3 maximum practice attempts before test trials. During the test trials, two attempts were made and the best score recorded. ***Instrument and recording***: A positive score indicated that the tip of the participants' fingers reached past the zero line indicated on the sit-and-reach test box while a negative score indicated that the tip of the fingers could not reach the zero reference line [18]. During execution of the test, knees were not allowed to bend otherwise the test was restarted.

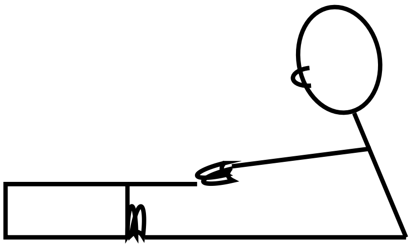


Figure 7-4: Sit-and-reach protocol

7.3.4.1.9 60-seconds push-up test

Warm up procedure: Participants performed the test barefooted for the assessment of upper-body muscular strength. A warm up procedure as explained before was conducted. The research assistant demonstrated the testing procedure and participants were allowed three (3) practice trials***. Test procedure:*** Players began in prone, with hands on the floor, thumbs shoulder width apart and elbows fully extended (Figure 7-5). Players were instructed to descend to the tester fist placed on the ground below the players' sternum and then ascend until the elbows are straight. Push-up action was to be continuous with a single rest of no more than 2 seconds permitted between repetitions. ***Instrument and recording***: Athletes performed the maximum number of push-ups as fast as possible in 60 seconds recorded using a stopwatch. If the athlete fails to complete the full 60 seconds due to fatigue, this failure was recorded together with the number full repetitions recorded and the time of drop-out [19].

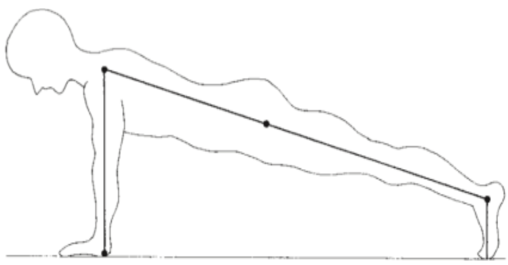


Figure 7-5: 60-s push-up test

7.3.4.1.10 2kg medicine ball chest throw (2-kg MBCT)

Warm up procedure: The 2-kg MBCT was for the assessment of upper-body muscular power. A warm up procedure as explained before was conducted. The research assistant would demonstrate the testing procedure and participants allowed three (3) practice trials. ***Test procedure****:* This test was conducted as described in literature to measure upper body power [20]. Players threw a 2kg medicine ball (dimensions=21.5cm) horizontally as far as possible while seated with the back, and legs straight. ***Instrument and recording****:* Distance was measured using the tape measure to the nearest 0.1m from the sitting line to where the ball initially landed with the higher of two trials measured. The two trials were separated by two minutes of recovery. Additional trials were allowed when the knees bent, and if the ball landed outside the circumscribed measuring area.

7.3.4.1.11 Wall Sit Leg Strength Test (WSLS) (sec)

Warm up procedure: The WSLS used for the assessment of lower-body muscular strength. A warm up procedure as explained for the other tests was conducted. The research assistant would demonstrate the testing procedure and participants allowed three (3) practice trials. ***Test procedure:*** The WSLS assessed static strength of the lower extremities. Participants stood comfortably with feet approximately shoulder width apart, with back against a smooth vertical wall. Participants would be instructed to slide the back down maintaining contact with the wall to assume a position with both knees and hip of 90° angle. However, the stopwatch was started when one foot was lifted off the ground and was stopped when the subject could not maintain that position or the foot was returned to the ground. The non-dominant leg was lifted to measure the leg strength of the dominant side and time was recorded in seconds.

7.3.4.1.12 Repeated high intensity exercise test (RHIE) (sec)

Warm up procedure: A pre-test warm procedure supervised by the research assistant was conducted first for 2 minutes, including shoulder-arm stretches, trunk rotation stretches with hands on the waist, bilateral quadriceps femoris stretches in standing, toes-touch stretching and jogging. ***Test procedure:*** The RHIE test, for assessment of repeated high-intensity exercise performance ability, was structured in two parts as described in the literature [21]. There was one for the backline players and the other test for forward players. For backline players, each player started with the toes behind a marker. They then completed three 20-m sprints before decelerating and jogging to the start (Figure 7-6). The sprints were performed on a 20-second turnaround, with approximately 16-17 second active recovery. The players were instructed to sprint with maximal effort. After completing 3 sprints (and after a 60-second recovery), the player moved to the side of the running lane and completed 2 tackles. They sprinted 10m to the tackle a bag (junior bag 117cm by 38cm, 15kg) held by a research assistant, driving it for 2 m. They then ran backward to the start and 20 seconds later completed a second tackle. A 20-second recovery followed the tackle shuttle. The player then repeated the 3 by 20-m sprint protocol and the tackle drill.

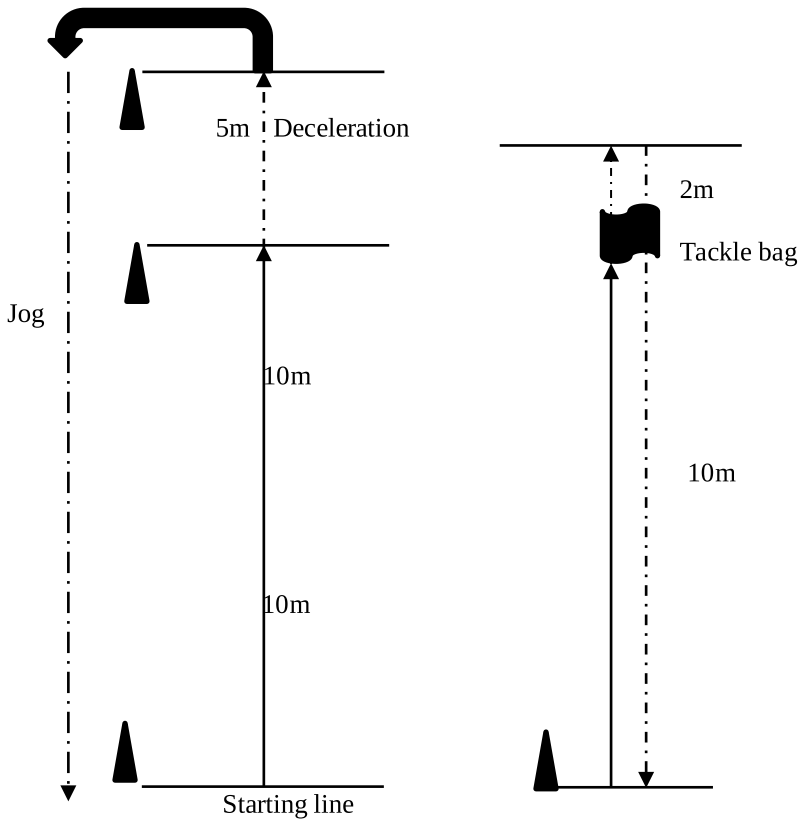


Figure 7-6: RHIE test for backline players

For the forwards, each player first completed 3 by 20-m sprints before decelerating and jogging to the start (Figure 7-7). Each participant was instructed to sprint to the best of their abilities. Each sprint was performed on a 20-second cycle, leaving 16- to 17-second recovery between sprint efforts. After the third sprint in each set and after a 60-second rest, the player moved to complete a *"scrum sled shuttle"*. This involved pushing a weighted (50 kg) one man scrum sled for 5 m in 1 direction and 5 m back to the start. The player completed this 4 times, with a 10-second rest between bouts. On completion of the scrum sled shuttle, the player was given 20 seconds to return to the sprint lane. Participants would then repeat the sprint shuttles (3 by 20 m) before moving to the tackle drill. After a 60-second rest, he sprinted 10 m and tackled a tackle bag driving it at least 2m. On completion of the tackle, players ran backward to the start line and repeated the tackle drill on 4 occasions; 20 seconds separated the start of each sprint to tackle. A final set of 3 sprints then concluded the test. Times were recorded for each sprint repetition (total of 9).

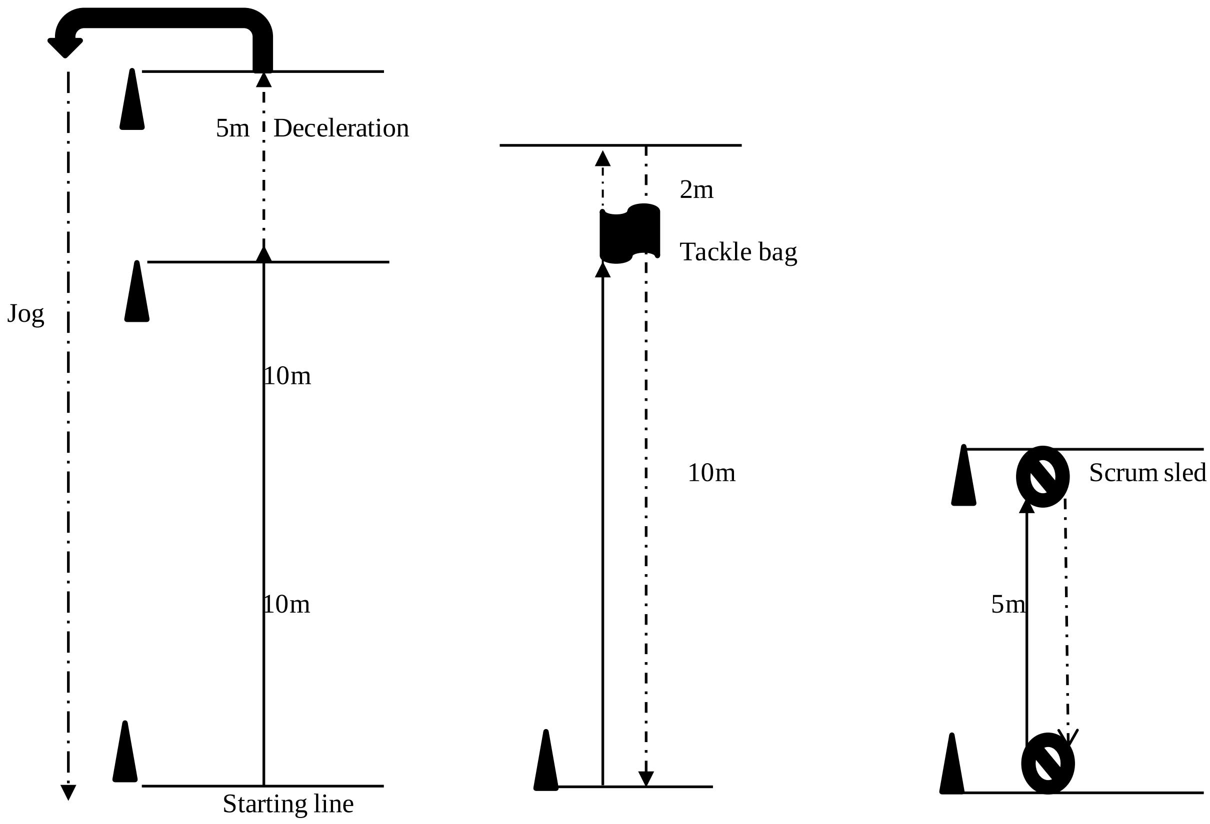


Figure 7-7: RHIE test for forward players

Instrument and recording: Total RHIE performance sprint time was taken as the sum of all three (3) sets of sprints (nine 20-m sprints in total as recorded by a stopwatch). Decrement in sprint performance was calculated as the difference in time taken (seconds) to complete the third set of sprints (sprints 7-9) compared with the total time taken to complete the first set of 3 sprints (sprints 1-3).

7.3.4.1.13 Yo-Yo intermittent recovery test level 1 (m)

Warm-up procedure: A pre-test warm procedure supervised by the research assistant was conducted first for 2 minutes as for the RHIE test. ***Test procedure:*** The Yo-Yo IRT L1 was conducted as previously described in literature [6] for the assessment of prolonged high intensity intermittent running ability/endurance. Players were required to run back and forth along a 20-m track, keeping in time with a series of signals on a compact disk. The frequency of the audible signals (and hence running speed) was progressively increased until subjects reach volitional exhaustion. The course was set up on a dry (grass) surface. Participant wore short and rugby t-shirts, and studded shoes for playing rugby. Starting from a stationary position, participants would run back and forth along the 20m track while keeping in time with the audio signals played from the compact disk. The players started after the beep and runs to opposite line. The players turned when the next beep goes. There were 2 research assistants at both lines to check if the player touches the line with 1 foot and if they keep in time with the audible signals. They also make sure the players don't start running back before the beep the sound. After about 1 minute, a sound indicated an increase in speed, and the beeps got closer together with time. If the line was reached before the beep, the subjects waited until the sound beeps before continuing. If the line was not reached before the beep, the participant was given a warning and would continue to run to the line, then turn and try to catch up with the pace within two more beeps. The test was stopped for that player after failing to reach the line (within 2 meters) for two consecutive ends after a warning. The research assistants were checking for this. ***Instrument and recording***: The number of complete laps run and shuttles were recorded. This was used to calculate the total Yo-Yo IRT L1 distance in meters.

7.3.4.1.14 One-repetition maximum back squat (kg) (1-RM BS)

Warm-up procedure: A pre-test warm procedure supervised by the research assistant was conducted first for 2 minutes as for the RHIE test. In addition, each participant performed two warm-up sets using a resistance that was approximately 40-60% of their estimated 1RM. ***Test procedure:*** The 1-RM BS was used for the assessment of lower-body muscular strength. All the participants had to be experienced with the squat protocol, having performed it for a minimum of two years before our assessment [22]. The participants were required to lower the barbell to a depth equivalent to at least 90 of knee flexion as visually determined by the researcher for the attempt to be considered successful and players had to return to the standing position to record 1-RM score [23-25]. The greater trochanter of the femur had to be aligned with the patella and on ascension the knee and hip had to be in full extension. If the set was successfully completed then weight was added and if not weight was reduced and another set attempted. A 3-5 minutes rest was provided between each set. This process of adding and removing was continued until a 1-RM was achieved [12, 13]. ***Instrument and recording:*** The players' 1-RM absolute scores were recorded in kgs and 1-RM relative scores were calculated as the 1-RM absolute scores divided by the body mass to provide a strength score relative to body mass.

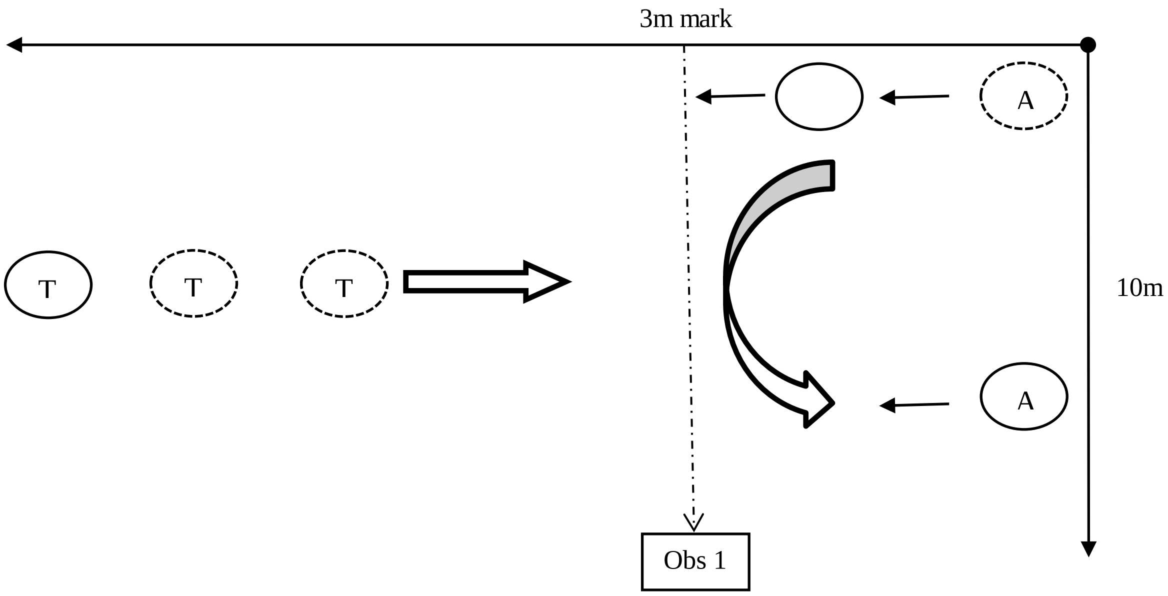
7.3.4.1.15 One-repetition maximum bench press (kg) (1-RM BP)

Warm-up procedure: A pre-test warm procedure supervised by the research assistant was conducted first for 2 minutes as for the RHIE test. In addition, each participant performed two warm-up sets using a resistance that was approximately 40-60% of their estimated 1-RM. ***Test procedure:*** The 1-RM BP was used for the assessment of upper-body muscular strength. All the participants had to be experienced with the press protocol with a minimum of two years before assessment [22]. Athletes lowered the barbell to touch the chest and push the barbell until the elbows were in extension [24]. Participants used a self-selected hand position and were required to lower the bar at approximately 90 degree angle at the elbows and then pressed the bar in a vertical position so that the arms are fully extended [26]. Participants need not to bounce the barbell off their chest or lose contact between the bench and their hips or the floor and their feet [22]. ***Instrument and recording:*** The players' 1-RM absolute scores were recorded in kgs and 1-RM relative scores were calculated as the 1-RM absolute scores divided by the body mass to provide a strength score relative to body mass.

7.3.4.1.16 Modified tackling proficiency test

Warm-up procedure: A pre-test warm procedure supervised by the research assistant was conducted first for 2 minutes, including shoulder-arm stretches, trunk rotation stretches with hands on the waist, bilateral quadriceps femoris stretches in standing, toes-touch stretching and jogging. ***Test procedure:*** This test was modified from previously used or mentioned tests in literature [27-32] for the assessment of tackling proficiency. A simulated rugby-specific match 2-on-1 scenario was simulated within a 10×10 m grid for the tackling test (Figure 7-8). A local rugby coach with 20 years of coaching rugby experience at senior and junior level served as an expert rater (obs 1) for the skill rating of the participants. Three players were used at one given time. The two attacking players (ball carriers) were former U19 rugby players recruited as research assistants for this test. They were instructed to advance from one side of the grid to the other and complete one pass each before being tackled by the defending player (test player). The test players were oblivious of the number of passes to be completed between the attacking players to mimic a real rugby scenario which is underlined by unpredictability. The attacking players were set at 4m apart from each other and 5m away from the tackler at the beginning.

The attacking players were allowed to make passes between them within the 3m while advancing forward. A line at 3m indicated where no more passes between the two attacking players were allowed. The test player was initially stationed 5m away from straight line marking the starting line of the attacking players. The procedure was for the test player to tackle the player with the ball. If the attacking player runs faster that the test player does not get him, the test was repeated. Demonstrations were given to enhance players understanding of the test and to provide them with the reference for the required match-like intensity. After one cycle of this protocol the players waited for a brief recovery period (1minute) on their feet at the opposite end of the grid before repeating the drill. Six test trials were conducted to allow the observer to observe the tackling skills under fatigue as well.



Key

T= Tackling Player Being Assessed; A=Passing and Receiving Player; =Ball passing direction

Figure 7-8: Modified tackling proficiency protocol

Instrument and recording: The observer assessed and scored each of those six trials based on the adopted and modified technical checklist. The observer rated each player in real time on their overall proficiency in each skill using a Likert scale *(0-not achieved completely; 1-partly achieved; 2-completely achieved relevant criteria)*. The expert rugby coach was given the assessment criteria two weeks prior to testing and it was discussed with them in detail. Preliminary tests to pilot the assessment criteria were conducted prior to the main study. The coach was under explicit instruction to refer to the criteria during the testing procedures. The technical criteria were as follows:

1. *Contacting the target in the centre of gravity/low body position*
2. *Contacting the target with at least one shoulder*
3. *Head to one side of the body*
4. *Arms showed readiness for tackling*
5. *Body position square/aligned*
6. *Arms completely wrapped around the target on contact when tackling*
7. *Leg drive on contact/ drive with the legs*
8. *Centre of gravity forward on base of support*
9. *Maintain grip until the attacking player is on ground*
10. *Turtle the player/ hold the player immobile on the ground/defensive shape*

An average of the tackling proficiency arbitrary scores from the six test trials was calculated to represent the test player test score for tackling. The tackling proficiency arbitrary scores were then expressed as percentage of the total possible scores to estimate the tackling proficiency percentage score.

7.3.4.1.17 Modified passing-for-accuracy over 7m test and passing ability skill test

Warm-up procedure: A warm up procedure as explained for tackling test was conducted. The research assistant would demonstrate the testing procedure and participants allowed three (3) practice trials. ***Test procedure:*** This test was used for combined assessment of passing skill ability and accuracy in passing for over a 7m distance modified from previous studies [16, 33, 34]. Only one player was tested at any given time. Participants commenced chest down, flat on the ground, and knees extended behind the starting line (Figure 7-9). They stood up on the word “GO” from a research assistant stationed at the starting line and would grab a rugby ball placed on the touch line and sprint in a zig-zag way on a 10m course set out using cones. The participants were instructed to run as quickly as possible. Upon entering the passing grid zone (measuring 3m by 3m) they were supposed to release the rugby ball and prepare to receive a pass from one of the expert coaches (E1) acting as a research assistant for the study. There were instructed to catch the ball and pass immediately at a moving target (R) placed at a 7m distance with a defensive player approaching to offer a hindrance (A). The pass had to be made from the centre of the passing grid zone. Another rugby expert (E2) rated the pass made by the first expert (E1) and if the pass was deemed bad, the test was repeated. The target (R) would have started at the starting line and moved slowly with the pace of the tested player in anticipation of receiving the ball. The target player used was former U19 elite rugby player acting as a research assistant for the research team.

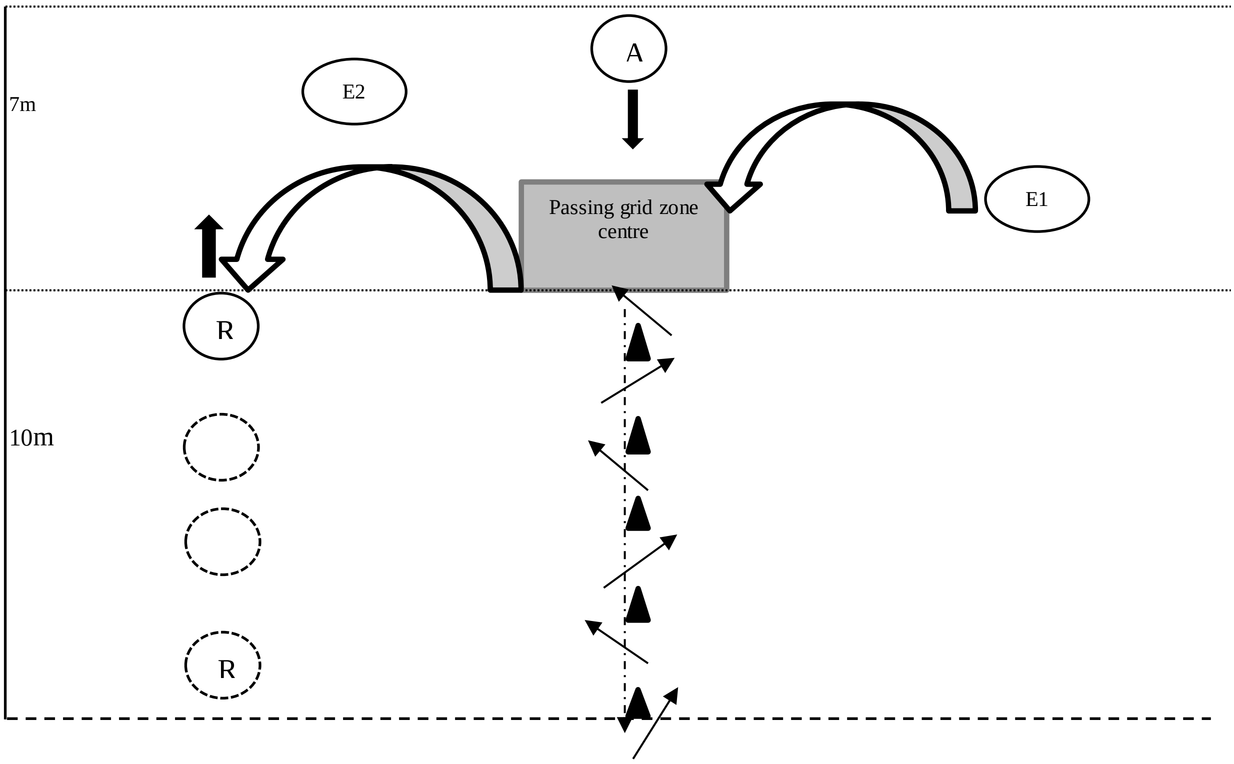
After each pass, the subject ran back to the starting line and repeats the test without starting in prone this time. They would start each 10m sprint at a 20sec cycle. This happened five times making it one set of passing ability assessment. The second set started 60seconds after the completion of the first set and would begin with the participant in prone again, and chest on the ground and repeating everything else alluded above. After completing the second set of five runs, the participant rested again for 60seconds before embarking on the last final set. Overall, the total passes made were 15 executed in three sets of 5. Participants decided on which side they preferred to pass depending on their hand dominance.

Instrument and scoring: The number of accurate passes made (passes caught) to the receiver (R) was determined by the lead author observing and expressed as percentage of the total passes made to give the passing accuracy (%) score for the participant. In addition, an expert rugby coach (E2) judged passing ability looking at the eight elements giving a passing ability score for each pass made looking at the technical elements utilised in the pass. The scoring was based on a dichotomous response scale: *0-not achieved; 1-achieved*. So each participant was assessed 15 times (3 sets of 5) and a score was recorded for each technical element. All the scores were then added for each test trial to give a total passing skill score reflecting passing ability score in arbitrary units. The technical criteria assessed the following and its detailed version is shown in Table 7-3 below:

1. *Pendulum action*
2. *Looking where pass is to be made*
3. *Single movement*
4. *Straight follow through of passing hand*
5. *Appropriate ball speed*
6. *Pass in front of the receiver*
7. *Receiver catches the ball*
8. *Receiver maintains stride/minimal breaking of the receiver pace to receive the ball.*

Table 7-3: The detailed version of the technical criteria

Technical criteria	Summarised version	Detailed explanation
1	pendulum action	Swing ball through in single motion in an 'up and down plane' (not across body)
2	Look where passing	look where passing without breaking the natural pace, postural and kinematic adjustments allowing the body to pass left or right
3	Single movement	Total movement should be achieved in one motion while running straight line
4	Straight follow through of passing hand	Straight follow through of passing hand
5	Ball speed	Appropriate ball speed
6	Pass in front of the receiver	Pass in front of the receiver
7	Receiver catches the ball	The point of a pass is for the receiving player to catch it. Accuracy judged on complete passes received
8	Receiver maintain stride	Minimal breaking of the receiver pace to receive the ball, and should catch the ball within his catching grid zone without accelerating fast to keep up with a fast pass.



R- Receiver; A-Attacking player; E1- Coach Expert 1(Passer); E2-Coach Expert 2 (Rater)

Figure 7-9: Protocol for passing ability and accuracy assessment

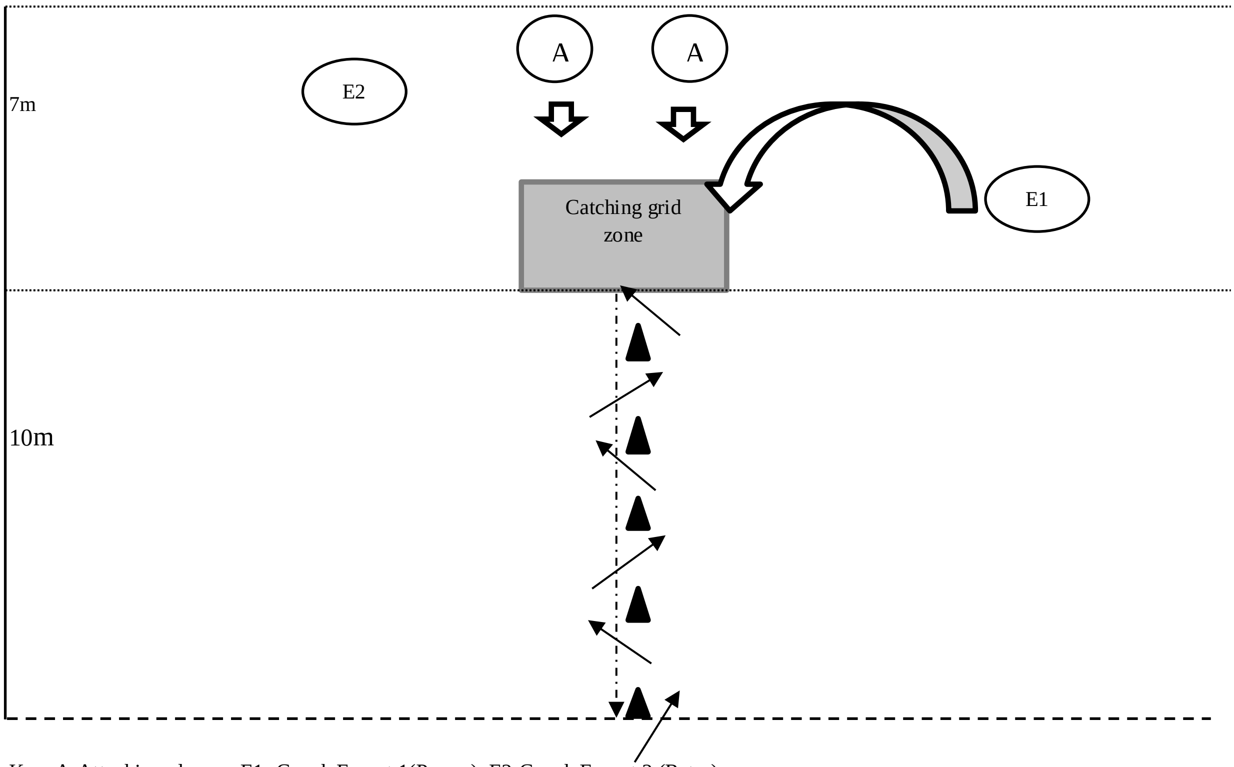
7.3.4.1.18 Running-and-catching ability test

Warm up procedure: Participant wore shorts and t-shirts. A warm up procedure as explained for tackling test was conducted. The research assistant would demonstrate the testing procedure and participants allowed three (3) practice trials. ***Test procedure****:* The protocol was similar to the passing protocol but modified from descriptions of Pienaar et al [33] and Gabbett et al [16] and was mainly designed for the assessment of catching ability skills test based on expert rating. Briefly, participants ran in a zig-zag fashion for 10m holding the rugby ball (Figure 7-10). Starting position of prone was similar as for the passing procedure. Upon entering the catching grid zone (measured 3m by 3m) the ball is passed immediately from 7m and the test player should show ability to catch the ball. The test was performed on a different day from the passing protocol to allow for independent assessment of the skills accurately.

Two player assistants providing defensive play were utilised in the protocol. Their duty was to provide cognitive recognition of impending attack to the test player for the passed ball to simulate match rugby situations. Their hidden aim was to compete for the ball as well with the tested player. The two assistants were placed equidistant from participant catching grid. There were also two coach experts acting as research assistants, one rated the technical ability of catching as a skill and the other one was helping with the decision on the quality of the pass made to the test participant. If the pass was deemed not suitable, looking at some of the key things highlighted under passing ability, then that pass will not be rated for catching. Otherwise a re-throw was done. If the pass was deemed acceptable and the test participant misses it was recorded as a missed catch and awarded corresponding scores.

Instrument and recording: There was a technical criteria used for assessment of running-and-catching ability. Each of the five criteria was assessed based on a Likert scale: *0 (failed completely to perform the activity), 1 (completely achieved)*. Participants were assessed 15 times (3 sets of 5) just like in the passing protocol. The idea is to see how the participants would fare before and after fatigue has set in. The total score per test trial was 5 aggregating to 75 after completion of 15 tests trial. The technical criteria looked at the following elements:

1. *Eyes on the ball/Focus on passer/ Body receptive to the pass*
2. *Hands up/elbows bent/*
3. *Fingers spread/palms out and thumbs up*
4. *Take the pass early/meet the ball early*
5. *Catch the pass/Hold the "body" of the ball and all this with minimal breaking of the natural or starting stride of the player.*



Key: A-Attacking players; E1- Coach Expert 1(Passer); E2-Coach Expert 2 (Rater)

Figure 7-10: Running-and-catching protocol

7.3.5 Statistical analyses

Data analysis was carried out using SPSS statistical software (Version 25.0). The Shapiro Wilk test assessed violations of normality for all continuous variables ($p<0.05$). Histograms, detrended and normal q-q plots, and box plots were also visually inspected to further assess normality. A pre-designed online excel spreadsheet was used to compute the age at peak height velocity (PHV) based on the predictive equations of Mirwald et al [10]. Years from PHV were calculated by subtracting the age at PHV from chronological age. Descriptive statistics (Mean±SD) were used to describe parametric data. Paired samples *t*-test evaluated for systematic bias between trials ($p<0.05$). Given the practical nature of the study, Cohen's *d* effect size (ES) statistic was used to determine the practical significance of observed differences between test-retest assessments. Cohen's *d* was the difference between group means for the test and retest performance scores divided by the pooled standard deviation (SD). The pooled SD was computed as the squares root of the squared sum of the standard deviation of the test and retest performances. The criteria for interpreting the magnitude of the ES were as follows: <0.2 trivial, 0.2-0.6 small, >0.6-1.2 moderate and >1.2 large [35, 36].

Relative reliability for each SCRuM test item was determined by calculating the two-way random intra-class correlation coefficient (ICC 2, 1) for absolute agreement of single measures using the alpha model. However, average ICC measures were reported for tackling proficiency test because an average of six test trials was recorded to represent participant tackling score. The 95% confidence interval (CI) was calculated for each ICC testing if each ICC was equal to zero using the F-ratio [37]. ICC values of ≥0.70 were considered satisfactory, values ≥0.75 were considered as good and values of ≥0.90 were categorised as excellent [38, 44]. To test for absolute reliability of the SCRuM test battery items, the standard error of measurement (SEM) was calculated for each test. The SEM provides expected trial to trial measurement error and was computed as standard deviation of the differences ($SD_{differences}$) between test-retest assessments divided √2 [39, 40]. The √2 accounted for the uncertainty associated with conducting two trials for each SCRuM test item [41]. To facilitate comparison of test reliability values between studies, the coefficient of variation (CV %) expressed the SEM as a percentage of the grand mean [40, 42] and an arbitrary CV boundary of <10% was considered acceptable for reliability [42]. At 95% CI, the smallest detectable change ($SDC_{95\%}$) for each test item was calculated by multiplying SEM with 1.96 and √2 [39]. The usefulness of the each SCRuM test item was judged by comparing the $SDC_{95\%}$ with the SEM [43]. Adopted from Darrall-Jones et al [43], if the SEM was less than the SDC, the test was considered as "good" and if the SEM was similar to the SDC, this was considered as "OK". However, where the SEM was greater than the SDC calculated, the test usefulness was considered "marginal" as the detection of real change (greater than the noise of the test) was not possible because of the associated error in measuring the test.

7.4 Results

There were 82 (41 U19 and 41 U16) male adolescent rugby players in the final sample. Table 7-4 depicts sample demographics and rugby-related information of participants by age category.

Table 7-4: Sample demographics and rugby-related information (N=82)

Variable	Elite U19 players (n=41)	Elite U16 players (n=41)
Age (years)		
Mean±SD (years)	17.5±0.85	14.9±0.31
Range (minimum-maximum) years	15.6-18.9	14.4-15.3
YPHV (mean±SD) years	1.93±0.53	0.64±0.92
Rugby playing experience (Mean±SD) years	4.95±0.74	2.49±0.51
Generic rugby positions		
Forwards, n (%)	20 (48.8)	21 (51.2)
Backs, n (%)	21 (51.2)	20 (48.8)
Specific regular rugby positions		
Props	7	6
Flanks	5	6
Locks	5	3
Centres	5	4
Fullbacks	4	2
Scrumhalf	4	6
Wingers	4	7
Fly half	3	2
Hooker	3	3
Eight man	1	2

SD= standard deviation, YPHV= years from peak height velocity; M=mean

There were no systematic changes between trials for most SCRuM test items, except for the bicep skinfold measure (p=0.04, ES=0.07) and Wall Sit Leg Strength (WSLS) test (p=0.01, ES=0.20) among elite U19 male adolescent rugby players (

Table 7-5). However, the magnitudes of the practical differences based on Cohen's *d* were "trivial" and "small" for these respective tests.

Table 7-5: Paired sample t-test and effect size calculations for elite U19s

Variable	Test	Re-test	Mean diff	Std diff	p	ES [95% C1]	Effect
Anthropometry							
Body mass (kg)	77.5±9.58	77.6±9.57	-0.06	0.26	0.13	-0.01[-0.03-0.04]	Trivial
Height (m)	1.73±0.06	1.73±0.06	0.00	0.01	0.82	0.00 [0.00-0.00]	Trivial
BMI (kgm^{-1})	25.9±3.27	26.0±3.27	-0.04	0.39	0.54	-0.03[-0.09-0.11]	Trivial
Biceps (mm)	6.71±3.62	6.46±3.38	0.24	0.73	**0.04***	0.07 [0.03-0.21]	Trivial
Triceps (mm)	9.44±2.95	9.56±2.76	-0.12	1.19	0.52	-0.04 [-0.12-0.16]	Trivial
Subscapular (mm)	12.8±2.74	12.9±2.59	-0.12	0.78	0.32	-0.04 [-0.12-0.16]	Trivial
Suprailiac (mm)	8.93±3.84	9.02±3.86	-0.10	0.77	0.42	-0.02 [-0.06-0.08]	Trivial
Abdomen (mm)	11.4±2.85	11.7±3.16	-0.27	1.40	0.23	-0.10 [-0.30-0.20]	Trivial
Thigh (mm)	9.98±2.48	10.0±2.45	-0.02	1.33	0.91	-0.01[-0.03-0.04]	Trivial
Calf (mm)	5.49±1.03	5.54±0.98	-0.05	0.63	0.62	-0.05 [-0.15-0.10]	Trivial
Sum of SKF (mm)	64.7±15.6	65.2±15.2	-0.44	2.63	0.29	-0.03 [-0.08-0.10]	Trivial
Physiological tests							
5m speed (sec)	1.10±0.03	1.11±0.04	-0.01	0.03	0.07	-0.28 [-0.83-0.27]	Small
10m speed (sec)	2.01±0.13	2.03±0.17	-0.02	0.13	0.23	-0.13 [-0.39-0.16]	Trivial
20m speed (sec)	3.25±0.17	3.22±0.21	0.03	0.08	0.06	0.16 [-0.16-0.47]	Trivial
40m speed (sec)	5.60±0.29	5.58±0.33	0.02	0.08	0.11	0.06 [-0.05-0.18]	Trivial
L-run agility (sec)	6.21±0.32	6.20±0.34	0.01	0.15	0.77	0.03 [-0.09-0.07]	Trivial
Vertical jump (cm)	47.8±3.81	48.2±3.75	-0.32	1.38	0.15	-0.11 [-0.32-0.10]	Trivial
Sit-and-reach (cm)	7.88±5.13	8.51±4.86	-0.63	2.01	0.05	-0.13 [-0.38-0.16]	Trivial
2-kg MBCT (m)	9.23±1.26	9.41±1.31	-0.18	0.59	0.05	-0.14 [-0.41-0.13]	Trivial
60-s push-up (sec)	49.7±9.97	50.7±10.6	-1.02	3.66	0.08	-0.10 [-0.29-0.09]	Trivial
WSLS (sec)	146.1±9.72	147.9±8.31	-1.85	4.11	**0.01***	-0.20 [-0.59-(-0.10)]	Small
1-RM BS (kg)	98.4±14.8	98.8±13.7	-0.44	2.94	0.35	-0.03 [-0.08-0.05	Trivial
1-RM BP (kg)	90.5±16.4	90.7±15.7	-0.35	3.39	0.51	-0.01 [-0.03-0.02]	Trivial
RHIE (sec)	39.3±2.96	39.7±2.72	-0.37	1.81	0.20	-0.14 [-0.42-0.18]	Trivial
Yo-Yo IRT (m)	1505.9±75	1522.4±87	-16.6	60.6	0.09	-0.20 [-0.60-0.30]	Small
Game skills tests							
Tackling (%)	87.9±8.44	89.5±8.57	-1.59	5.96	0.10	-0.19 [-0.56-0.18]	Trivial
Passing Ability (au)	116.2±2.13	116.5±1.47	-0.29	1.38	0.18	-0.16 [-0.48-0.13]	Trivial
Pass Accuracy (%)	89.3±7.28	90.7±5.75	-1.47	6.58	0.16	-0.21 [-0.63-0.24]	Small
Catching (au)	74.0±1.07	74.2±0.91	-0.22	0.76	0.07	-0.20 [-0.59-0.19]	Small

Mean diff=Mean difference (test score-retest score); Std diff= Standard deviation difference; df=degrees of freedom; p value= 2 tailed probability value; SKF=Skinfolds; *=significant difference ($p<0.05$); ES= Cohen's d effect size statistic with the 95% confidence interval; 2-kg MBCT=2 kg medicine ball chest throw; WSLS=Wall sit leg strength; 1RM BS/BP=One repetition maximum back squat/bench press; RHIE=repeated high intensity exercise; Yo-Yo IRT= Yo-Yo intermittent recovery test; Tackling (%)=Tackling proficiency test; m=metres; kg=kilograms; sec=seconds; au=arbitrary units; cm=centimetres. Catching=Running and catching ability test; pass accuracy=passing accuracy ability skills test; N=sample size.

The ICCs, SEM, and $SDC_{95\%}$ results for SCRuM test items per age category are shown in

Table 7-6 and Table 7-7. Overall, the ICCs for the SCRuM test items ranged between 0.49 and 1 for older male adolescent U19 rugby players. Evidence of low test-retest reliability were found only for the 5m speed test (ICC=0.52; 95% CI=0.27-0.71), 10m speed test (ICC=0.64; 95% CI=0.42-0.79) and passing-for-accuracy 7m test (ICC=0.49; 95% CI=0.22-0.69). The SR test exhibited greatest variability with a CV of 17.3%. The $SDC_{95\%}$ values for all SCRuM test items were greater than the SEM values indicating the usefulness of the tests in detecting in real changes. For the elite U16 male adolescent rugby players (Table 7-7), the ICCs for the SCRuM test items ranged between 0.52-0.99 with CV ranges between 0.56-6.05%. Evidence of low test-retest reliability were found only for the 5m speed test (ICC=0.63; 95% CI=0.39-0.78), and passing-for-accuracy over 7m test (ICC=0.52; 95% CI=0.46-0.58).

Table 7-6: Measures of reliability for the SCRuM test items for U19s

Variable	ICC [95% CI]	SEM [95%CI]	CV (%) [95%CI]	SDC [95%CI]
Anthropometry				
Body mass (kg)	1.00 (0.99-1.00)	0.19 [0.09-0.31]	0.24 [0.10-0.35]	0.52 [0.39-0.78]
Height (m)	0.97 (0.95-0.99)	0.01 [0.01-0.03]	0.56 [0.43-0.67]	0.03 [0.03-0.05]
Biceps (mm)	0.98 (0.95-0.99)	0.52 [0.10-1.10]	7.88 [6.60-9.00]	1.44 [1.24-1.67]
Triceps (mm)	0.92 (0.85-0.95)	0.84 [0.20-1.40]	8.84 [6.34-9.10]	2.33 [2.08-2.55]
Subscapular (mm)	0.96 (0.92-0.98)	0.55 [0.42-0.64]	4.29 [3.12-5.13]	1.53 [1.01-1.89]
Suprailiac (mm)	0.98 (0.96-0.99)	0.54 [0.20-1.11]	6.05 [4.20-7.03]	1.51 [1.34-2.16]
Abdomen (mm)	0.89 (0.81-0.94)	0.99 [0.60-1.35]	8.57 [6.12-8.89]	2.74 [2.23-3.17]
Thigh (mm)	0.86 (0.75-0.92)	0.94 [0.30-1.50]	9.43 [7.24-9.89]	2.61 [2.03-2.87]
Calf (mm)	0.81 (0.66-0.89)	0.45 [0.20-0.68]	8.09 [7.01-9.27]	1.24 [1.01-1.45]
Sum of Skinfold (mm)	0.99 (0.97-0.99)	1.86 [1.04-2.68]	2.86 [1.20-3.45]	5.15 [3.14-6.17]
Physiological tests				
5m speed (sec)	**0.52 (0.27-0.71)**	0.02 [0.01-0.02]	1.94 [1.48-2.40]	0.06 [0.04-0.06]
10m speed (sec)	**0.64 (0.42-0.79)**	0.09 [0.06-0.09]	4.50 [3.60-5.40]	0.25 [0.10-0.35]
20m speed (sec)	0.90 (0.81-0.94)	0.06 [0.04-0.07]	1.83 [1.20-2.40]	0.16 [0.08-0.24]
40m speed (sec)	0.97 (0.94-0.98)	0.05 [0.03-0.05]	0.95 [0.35-1.55]	0.15 [0.08-0.21]
L-run agility (sec)	0.90 (0.82-0.95)	0.11 [0.07-0.15]	1.72 [1.10-2.30]	0.30 [0.19-0.37]
Vertical jump (cm)	0.93 (0.88-0.96)	0.97 [0.54-1.14]	2.03 [1.03-2.90]	2.70 [1.90-3.46]
Sit-and-reach (cm)	0.91 (0.84-0.95)	1.42 [1.08-1.57]	17.3 [11.1-19.2]	3.93 [2.89-4.17]
2-kg Medicine Ball Chest Throw (m)	0.89 (0.80-0.94)	0.42 [0.20-0.67]	4.48 [3.40-6.10]	1.16 [0.98-1.27]
60-s push-up (sec)	0.93 (0.88-0.96)	2.59 [1.34-3.07]	5.15 [3.12-7.04]	7.17 [6.07-7.98]
Wall Sit Leg Strength (sec)	0.88 (0.76-0.94)	2.90 [1.87-3.98]	1.98 [0.78-2.94]	8.05 [6.78-9.34]
1-RM Back Squat (kg)	0.98 (0.96-0.99)	2.08 [1.45-3.45]	2.11 [1.34-2.95]	5.77 [3.57-6.17]
1-RM Bench Press (kg)	0.98 (0.96-0.99)	2.40 [2.02-2.67]	2.64 [2.54-2.87]	6.64 [5.67-7.12]
RHIE (sec)	0.79 (0.65-0.89)	1.28 [0.65-1.71]	3.24 [2.10-4.12]	3.55 [3.34-3.98]
Yo-Yo IRT (m)	0.72 (0.53-0.84)	42.88 [34.2-67.4]	2.83 [2.09-3.14]	118.87 [101.1-137.9]
Game skills tests				
*Tackling (%)	0.86 (0.74-0.93)	0.84 [0.35-1.40]	4.75 [2.13-5.13]	2.34 [1.67-3.01]
Passing Ability Skills test (au)	0.71 (0.52-0.83)	0.98 [0.30-1.50]	0.84 [0.45-1.23]	2.71 [2.01-3.14]
Passing Accuracy Skill test (%)	**0.49 (0.22-0.69)**	4.66 [3.40-5.70]	5.17 [3.76-7.12]	12.91 [9.03-14.78]
Running-and-catching ability (au)	0.70 (0.37-0.81)	0.54 [0.10-1.00]	0.72 [0.24-1.03]	1.49 [1.04-2.17]

Bold indicates low ICC values; ICC=intraclass correlation coefficient; 95% CI=95% confidence interval; SEM=standard error of measurement; CV=coefficient of variation; SDC=smallest detectable change; *ICC value expresses absolute agreement for average measures; BMI=Body mass index, 1RM BS and BP=One repetition maximum back squat and bench press; Yo-Yo IRT= Yo-Yo intermittent recovery test; RHIE=repeated high intensity exercise test measured in seconds; au =arbitrary units; catching=running-and –catching ability skills test.

Table 7-7: Measures of reliability for the SCRuM test items for U16s

Variable	ICC	95% CI	SEM [95%CI]	CV (%) [95%CI]	SDC [95% CI]
Anthropometrics					
Body mass (kg)	0.99	0.99-1.00	0.43 [0.27-0.67]	0.67 [0.34-0.98]	1.19 [0.76-1.5]
Height (m)	0.99	0.99-1.00	0.01 [0.01-0.03]	0.56 [0.32-0.67]	0.03 [0.02-0.04]
Biceps (mm)	0.98	0.96-1.00	0.26 [0.13-0.37]	4.51 [3.34-5.43]	0.72 [0.45-1.10]
Triceps (mm)	0.99	0.97-1.00	0.42 [0.34-0.61]	4.29 [2.02-6.12]	1.16 [0.87-1.56]
Subscapular (mm)	0.99	0.99-1.00	0.56 [0.25-0.92]	5.17 [3.17-6.17]	1.55 [1.23-2.10]
Suprailiac (mm)	0.98	0.95-1.00	0.32 [0.18-0.56]	3.89 [2.12-4.34]	0.89 [0.67-1.34]
Abdomen (mm)	0.97	0.95-1.00	0.69 [0.44-0.82]	6.05 [4.56-7.35]	1.91 [1.23-2.89]
Thigh (mm)	0.98	0.96-1.00	0.31 [0.27-0.35]	2.89 [1.11-3.78]	0.86 [0.45-1.13]
Calf (mm)	0.97	0.94-0.98	0.20 [0.09-0.32]	3.14 [2.16-4.14]	0.55 [0.43-1.79]
Sum of Skinfold (mm)	0.99	0.99-1.00	2.74 [1.23-4.15]	4.32 [2.24-5.12]	7.59 [5.23-8.19]
Physiological tests					
5m speed (sec)	**0.63**	0.39-0.78	0.03 [0.03-0.05]	2.43 [1.23-2.89]	0.08 [0.04-0.10]
10m speed (sec)	0.87	0.75-0.95	0.05 [0.04-0.06]	2.10 [1.89-2.25]	0.14 [0.08-0.25]
20m speed (sec)	0.92	0.85-0.95	0.07 [0.05-0.09]	1.87 [1.54-1.90]	0.19 [0.11-0.26]
40m speed (sec)	0.97	0.95-0.99	0.07 [0.07-0.09]	1.20 [1.10-1.34]	0.19 [0.14-0.25]
L-run agility (sec)	0.90	0.82-0.98	0.16 [0.08-0.25]	2.50 [0.98-3.14]	0.44 [0.32-0.57]
Vertical jump (cm)	0.92	0.89-0.95	0.84 [0.54-1.11]	2.19 [1.23-3.04]	2.33 [1.37-2.67]
Sit-and-reach (cm)	0.88	0.84-0.92	0.29 [0.12-0.45]	4.67 [3.34-5.04]	0.80 [0.67-1.26]
2-kg MBCT (m)	0.91	0.87-0.95	0.10 [0.07-0.12]	1.45 [0.98-2.11]	0.28 [0.16-0.75]
60-s push-up (sec)	0.94	0.85-0.99	1.10 [0.87-1.35]	2.87 [2.11-3.09]	3.05 [2.09-3.98]
Wall Sit Leg Strength (s)	0.97	0.95-0.99	4.15 [3.76-4.54]	3.14 [2.13-4.34]	11.5 [7.12-13.6]
Yo-Yo IRT (m)	0.92	0.84-0.99	38.4 [27.3-50.5]	2.94 [2.54-3.16]	106.4 [98.6-111.3]
Rugby game skills					
*Tackling proficiency (%)	0.74	0.70-0.79	4.25 [3.35-5.15]	5.12 [3.76-6.13]	11.78 [8.34-12.67]
Passing Ability (au)	0.81	0.74-0.85	1.32 [1.10-1.51]	1.25 [1.01-2.56]	3.66 [2.23-4.12]
Pass Accuracy (%)	**0.52**	0.46-0.58	3.17 [2.09-5.35]	4.13 [2.67-5.12]	8.79 [7.12-9.34]
Catching (au)	0.75	0.62-0.88	1.35 [1.13-1.67]	1.87 [1.09-3.12]	3.74 [2.67-3.99]

Bold indicates low ICC values; ICC=intraclass correlation coefficient; 95% CI=95% confidence interval; SEM=standard error of measurement; CV=coefficient of variation; SDC=smallest detectable change; *ICC value expresses absolute agreement for average measures; BMI=Body mass index, 1RM BS and BP=One repetition maximum back squat and bench press were not measured for the U16s so was the RHIE; Yo-Yo IRT= Yo-Yo intermittent recovery test; RHIE=repeated high intensity exercise test measured in seconds; au =arbitrary units; catching=running-and –catching ability skills test.

7.5 Discussion

The purpose of this study was to evaluate test-retest reliability of each of the component test items in the fifth version of the SCRuM test battery. Establishment of reliability is an extremely important step in test battery development as it informs on the capacity of test items to differentiate participants or maintain the same relative order of participants in replicate measures under similar conditions [43, 44, 45]. The ICC is the most commonly reported sample statistic providing evidence of relative reliability in the literature [37]. It thrives on increased variability in the sample population for the measured construct and decreased measurement error [39].

During test-retest reliability study, participants had two familiarisation session for each age category conducted separately for field-based and gym-based assessments and were also allowed up to three practice trials. Given prior familiarisation, it is highly likely that "learning effects" were removed. Some of the tests (i.e. 1-RM BS, WSLS, 60s push-up) were regularly utilised in the local context during habitual training. All this ensured that participants were completely aware of test procedures before the experimental trials minimising the possible effects of acute fatigue. All the tests were conducted during training time at research settings (i.e. school rugby fields and gymnasium) familiar with the participants. Test standardisation was ensured throughout the test-retest experimental sessions through strict use of SCRuM test battery manual. Collectively, this probably explains the lack of systematic bias in consecutive trials and high relative reliability for majority of SCRuM test items among elite U16 and U19 male adolescent rugby players.

Among 82 elite U16 and U19 male rugby players, most SCRuM test items demonstrated no systematic bias, low CV% values and high ICCs suggesting absolute and relative reliability when the assessments are made during the 'in-season' phase. These results possibly reflect the careful manner in which SCRuM test items were implemented and temporal stability in the measured construct over the interval measured. Overall, high ICCs could be attributed to large between-subject variability observed for most test performances. This variability could potentially stem from natural differences in participant abilities, player heterogeneity or varied rugby experience. The sample population in the present study had varied rugby experience and involved a mix of players playing in distinct positions having different anthropometric, physiological and game-specific skills commensurate with positional demands (Table 7-4).

As expected and regardless of age category, good to excellent ICCs were shown for all anthropometric variables (ICCs=0.81-1.00). However, 12 of the 14 physiological tests administered to U19 male adolescent rugby players showed good to excellent relative reliability (ICCs=0.72-0.98). Tests found reliable included: 20m and 40m speed, modified L-run agility, VJ, SR, 60-s push-up, 2-kg MBCT, WSLS, RHIE, 1-RM BS, 1-RM BP, and the Yo-Yo IRT L1. Three tests (tackling, passing and catching) of the four rugby-specific game skills assessed had acceptable reliability (ICCs=0.70-0.86). These findings suggest that all these tests warrant inclusion in the SCRuM test battery for possible profiling of U19 male adolescent rugby players provided there is adequate participant familiarisation and test standardisation. On the other hand, 10 of the 11 physiological tests showed acceptable to high ICCs for the U16 players. The tests include 10m speed, 20m speed, 40m speed, modified L-run agility, VJ, 60-s push-up, SR, 2-kg MBCT, WSLS and the Yo-Yo IRT L1. Tackling, passing and catching ability tests also had acceptable reliability values.

The 10m sprint tests showed low relative reliability among U19s whereas the 5m speed test was unreliable in both U16s and U19s. This questions the appropriateness for inclusion of these speed tests in the SCRuM test battery for the respective age categories given the wide CI. Furthermore, the SEM of each speed test ranged from 0.02 to 0.09 seconds indicating error consistency across the speed distances for older male adolescents. However expressed as CV%, the SEM increased with short speed distances and decreased with longer distances. For example, the CV% for 10m speed test was 4.50 compared to 0.95 for 40m speed test. These findings indicate that the 40m speed test is more reliable compared to the 10m speed test among U19 rugby players. Alternatively, the 20-m speed test was more reliable (CV%=1.83) compared to the 10m speed test but less reliable relative to the 40-m speed test. These findings of high reliability for longer sprints above 20m among U19s were found for the U16s and are comparable with previous findings reported elsewhere [43]. The low reliability of the 10m speed test among U19 male adolescent rugby players was comparable to other studies. Dobbin et al [40] reported ICC (CV %) of 0.69 (4.9) for 10m speed test among 50 U19 academy rugby league players (age 17.1±1.1years; stature=181.3±6.3cm; body mass=89.0±11.6kg). However, besides differences in sample size and sport, there were methodological differences between Dobbin et al [40] study and our study (i.e. use of timing gates vs. electronic handheld stopwatch; three repeated measures vs. two repeated measures). In contrast, Gabbett et al [19] reported high ICCs (CV %) for 5-m and 10-m speed test of 0.84 (3.2) and 0.87 (1.9) respectively among 42 adult rugby league players (age=23.6±5.3yrs). Methodological, sport and population differences partly explain the differences in the ICC results between studies. Reliability parameters depend on variation in the population sample for the measured construct and results have external validity to populations with similar variation [39].

Another key but unexpected finding was the low relative reliability for the passing-for-accuracy 7m test in both age categories. This is explained by less variability between participants evidenced by smaller standard deviations in test and re-test scores. No previous study has reported the relative reliability of the passing-for-accuracy 7m test among U16 or U19 male adolescent rugby players referencing ICCs values. Pienaar et al [33] reported test-retest correlation (r=0.66) and 95% Limits of Agreement (LoA) suggesting moderate reliability among thirty-six 10-year old schoolboys with varied rugby experience. Whilst the present study used ICCs, Pienaar et al [33] used Pearson's correlation coefficient (*r*) to report test-retest reliability rendering comparisons difficult. Nonetheless, use of *r* has been criticised in contemporary literature since it evaluates linearity of test scores in repeated measures [45]. Instead, the ICC has been the most frequently reported parameter for relative reliability relating subject variability in test performance to the measurement error [39, 46].

The low reliability of the passing-for-accuracy 7m test in the present study could also be linked to test novelty. Unlike previous tests which had stationary rugby participants passing the ball to a static object placed 7m away and being judged on the accuracy of hitting the target [27, 33, 34], the present study had a dynamic recipient catching a pass from a running player. The test also uniquely included a research assistant offering standardised defensive play to the tested player. All this was designed to test passing-for-accuracy as an open skill simulating real game situations. However, given the low reliability, it is possible that the test was relatively easy for both U16 and U19 rugby players to achieve consistent discriminative performances. To minimise measurement errors, critical test elements such as running velocity of the tested and target player and positioning in the passing grid zone for executing the pass may need careful consideration in future modification of the test.

All SCRuM tests showed acceptable variability (CV<10%) indicating good agreement between test retest scores, except for the SR test among U19 rugby players. The SR test showed greatest variability (CV=17.3%) and paired samples t-test results showed almost statistically significant differences between test-retest assessments (p=0.05). Thus, it is possible that SR test lacked standardisation resulting in the observed mean scores between test-retest assessments. With a mean difference between trials of -0.63, learning effect could have potentially influenced test-retest results for SR. This probably creates a need for an extra familiarisation trial for the SR test in future studies or assessing test stability in more than two repeated measures.

7.5.1 Strengths and limitations of the study

The study utilised a relatively larger sample size than commonly used in similar studies reporting reliability of anthropometrical and performance tests in rugby. The response and test completion rate was high eliminating the effect of non-participation bias and missing information on test results. However, the study had some limitations. Wind speed was not measured in this study and may have an impact on sprint speed. Increasing the sample size and the number of trials could have improved the absolute reliability of SR test; however, this was not possible in this study because of time constraints and player availability. We choose a pragmatic approach to evaluate the reliability of the test items by conducting the study during the competitive season and the residual fatigue from training and competitive matches could have affected optimal performance from participants. This pragmatic approach was adopted because we were unable to control training activities and match exposure and these factors have a meaningful influence on test reliability. During test-retest study, no attempts were made to standardise the timing, type and quantity of food/fluid intake. It should also be noted that the Mirwald et al [10] equation used to determine age at peak height velocity as an index of biological maturity was determined in a different population among Canadian children and the applicability of this equation to a Zimbabwean population is questionable. In addition, reliability coefficients are population specific [37] and depend on the variability of the outcome in the studied population hence the need to have studied reliability of the SCRuM test items in all the age groups and playing standards and not just for the elite teams of U19 and U16.

7.6 Conclusion

Regardless of age category, good to excellent ICCs were shown for all anthropometric variables. Physiological and game skills tests administered to U19 male adolescent rugby players which showed good to excellent relative reliability and acceptable absolute reliability included: 20m speed, 40m speed, L-run, VJ, 60-s push-up, 2-kg MBCT, WSLS, RHIE, 1-RM BS, 1-RM BP, Yo-Yo IRT L1, tackling, passing ability and running-and-catching ability test. Among U16 players, 10m speed, 20m speed, 40m speed, L-run, VJ, 60-s push-up, SR, 2-kg MBCT, WSLS, Yo-Yo IRT L1, tackling, passing ability and running-and-catching ability test also had acceptable reliability values. All these tests warrant inclusion in the SCRuM test battery for possible profiling of U19 and U16 male adolescent rugby players during the 'in-season' phase provided there is adequate participant familiarisation and test standardisation. The test-retest ICCs and measurement errors are generalizable to other young athletes in this population, which will be useful to examine the training and growth and development necessary to observe meaningful improvements (See supplementary file 1 and 2) in these performance tests.

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8 CHAPTER 8: CONSTRUCT VALIDITY STUDY

8.1 Introduction

This chapter constitute the second part of Phase III (main study). A research article concerned with answering the study primary research questions will be presented here. Following the test-retest reliability study presented in the previous chapter, this main study chapter aims to answer the three primary research questions justifying the conduction of this study which are outlined in Chapter one, sub-section 1.4.1.

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RESEARCH ARTICLE Open Access

Anthropometric, physiological characteristics and rugby-specific game skills of schoolboy players of different age categories and playing standards

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Abstract

Background: Rugby is increasingly gaining popularity among school-aged male junior players in countries hardly known for dominating international rugby, such as Zimbabwe. Given rugby combativeness, participating adolescents should possess qualities or skills commensurate with the physical demands of the sport for effective participation. This study investigated the independent and interactive effects of age category and playing standard on anthropometric, physiological characteristics and rugby-specific game skills among Zimbabwean athletes.

Methods: Two hundred and eight elite, sub-elite and non-rugby players competing at Under 16 and Under 19 age categories were assessed using the School Clinical Rugby Measure (SCRuM) test battery. Participants underwent height, sitting height, mass, skinfolds, speed, agility, upper-and-lower muscular strength and power, prolonged high-intensity intermittent running ability, tackling, passing and catching assessments in a cross-sectional experimental design.

Results: Age categories had significant main effect on all SCRuM test items except sum of seven skinfolds ($p = 0.45$, $\eta^2 p = 0.003$). Playing standard had significant main effects for all variables except height ($p = 0.40$, $\eta^2 p = 0.01$) and sum of seven skinfolds ($p = 0.11$, $\eta^2 p = 0.02$). Specifically, upper-and-lower muscular strength and power, prolonged high-intensity intermittent running ability, tackling, passing and catching improved with increasing playing standards. However, two-way analysis of variance only demonstrated significant interactions between the effects of age category and playing standards for vertical jump height (VJ) test, 2-kg medicine ball chest throw (2-kg MBCT) test, Yo-Yo intermittent recovery test level 1 (Yo-Yo IRT L1), and tackling and catching tests. Yo-Yo IRT L1, VJ, tackling and catching tests demonstrated greater discriminative ability among Under 16 s, whereas the 2-kg MBCT test showed better ability in Under 19 s.

Conclusion: All SCRuM variables except skinfolds improved with age, highlighting relative sensitivity in differentiating older from younger athletes. However, the discriminative ability by playing standards for VJ, 2-kg MBCT, Yo-Yo IRT L1, tackling and catching ability tests was age-dependent. These findings informs on general attribute development in junior rugby players with age and on specific players attributes in need of monitoring for attainment of elite status at U16 or U19 level.

Keywords: Adolescents, Rugby union, Anthropometric, Physiological, Rugby-specific game skills

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8.2 Background

Worldwide, burgeoning talent identification (TID) and long-term player development programmes have seen an increased number of male adolescents from a wide age range playing rugby union (rugby, RU) at different competitive levels in schools or academies [1, 2]. However, regardless of playing standard and age category, adolescent RU is a highly demanding physical and skill-based sport characterised by intermittent execution of high-intensity activities such as sprinting and tackling [3-7]. As such, adolescents playing competitive rugby require well-developed physical or physiological qualities and game skills for effective participation and team success. Accordingly, RU coaches are constantly seeking knowledge on junior players attributes linked to elite performance and how these attributes evolve with age for longitudinal maintenance of team success.

A plethora of studies have investigated the independent effects of age category or playing standard on cross-sectional test performances of junior rugby players. However, with junior athletes' performances likely to be determined by the complex interaction of a number of factors such as age and training-related factors, there seems to be limited understanding of the interactive effect of age category and playing standard on development of junior rugby players' attributes. This knowledge provides insight into the combined effect of age and training efforts on performance differences for rugby players of different playing standards, information which has specific implications on training and player development across various age categories and competitive levels.

Variably, anthropometric, physiological characteristics and game skills have been shown to improve across annual age categories [1, 8-11]. For example, Darrall-Jones et al [11] showed that body mass and height, but not skinfolds, of elite RU players increased significantly across Under 16 (U16), U18 and U21 age categories. Durandt et al [8] showed that elite U18 RU players had better scores for upper-body muscular strength and aerobic fitness compared to elite U16s, but not for speed and agility. Catching and passing-for-accuracy abilities were shown to increase from U16s to U18s for elite adolescent RU players [9]. Collectively, most of these studies provide vital cross-sectional information on performance differences of elite RU players across age categories, highlighting the primary influence of age or maturity-related factors in attribute development. The age category differences may allow coaches to monitor development of physical and technical attributes and adopt effective training strategies and programmes that minimise performance gaps between players of different age categories assisting with smooth developmental transition [10]. However, given the possibility that performance differences between younger and older athletes are likely to be related to growth and development-related process regardless of playing standard or sport, the common limitation with these studies has been the lack of a control group possibly including sub-elite rugby players or age-matched male adolescents playing a different sport. Possibly, this would allow for a comparative understanding of the relative effect of age category on performance differences across varying playing standards or sports.

Previous studies investigating the influence of playing standard on RU players attributes have established that anthropometric, physiological characteristics and game skills improve with increasing playing standards [12-16]. Body mass was greater in elite U16 RU athletes from a country known to have higher rugby playing standards compared to elite U16 players derived from a country known to have lesser rugby standards [16]. Jones et al [12] showed that upper-body muscular strength, 40-m speed, and aerobic fitness contribute to higher playing standard of U18 academy players when compared to lower-level U18 schoolboy rugby players. However, conflicting results have been reported for sum of skinfold thickness measurements [16-20]. In related intermittent sports, lower-body muscular power and agility discriminated U16 elite from sub-elite soccer players [21], whilst elite U16 rugby league (RL) players had better speed, agility, and aerobic capacity compared to sub-elite players [22]. The influence of differing playing standards on player performances may facilitate understanding of specific attributes important for the attainment of elite status, creating a strong foundation for launching targeted training interventions and TID initiatives in junior rugby. Although providing helpful information in identifying important characteristics for elite performance at a distinct age category, the above-cited studies largely assume that junior rugby players' performances are mainly influenced by differing playing standards or training-related exposures [23], and ignore biological maturation effects, age-related changes and possible interaction effects between age category and playing standards on performance outcomes.

With longitudinal studies hinting on different rates of attribute improvement for players depending on playing abilities and age category [24, 25], it is plausible to hypothesise for significant interactions between age category and playing standard on test performances for athletes. However, it is unclear from previous cross-sectional studies whether age-category differences are similar or different across playing standards and how these differences would compare if competitive rugby players are compared to age-matched non-rugby players playing a different competitive sport. Test performances for non-rugby players are also likely to improve with increasing age category similar to rugby players, however sports-specific differences in training exposure and playing standard may exert additional influence. Comparing anthropometric, physiological characteristics and game skills, the current study examined the independent influence of age category (U19s vs. U16s), playing standard (elite vs. sub-elite vs. non-rugby) and the interaction effects (age category×playing standard) on test performances. Based mainly on review findings of Till et al [19] and specific literature findings on rugby-specific game skills [1, 9], it was hypothesised that:

(i) *Anthropometric (except for sum of skinfolds which would remain stable), physiological characteristics and skill ratings would improve with increasing age category.*

(ii) *Anthropometric, physiological characteristics and rugby-specific game skills would improve with increasing playing standard.*

(iii) *There would be significant interactions between the effects of age category and playing standards on test performances.*

8.3 Methods

8.3.1 Study design, research setting and participants

To test study hypotheses, a cross-sectional design was employed to compare participant performances based on the School Clinical Rugby Measure (SCRuM) test battery. The processes involved in developing the test battery have been explained elsewhere [26-30]. Two hundred and eight (208) schoolboys participated in this study and were derived from three schools. Elite U16 (n=41) and U19 (n=41) rugby players were recruited from one state school based in Harare, Zimbabwe playing competitive rugby in the SESRL. The SESRL is the most competitive schoolboy rugby league in the country [26]. The school was purposively-selected since they were the defending champions and had won the SESRL thrice in the last five seasons. All sub-elite participants (U16=41, U19=46) were recruited from a Harare-based private school playing rugby in the CESRL. The CESRL represents a second-tier schoolboy rugby league in Zimbabwe [26]. Cricket players (U16s=29, U19s=21) represented the non-rugby playing group and were recruited from one of the “top” cricket-playing state high schools based on 2018 provincial inter-scholastic competitions. The justification for including an elite cricket players involved incorporating a second comparative, convenient group of schoolboy athletes playing a competitive sport known to have different physical and technical demands than rugby [31]. All invited players were informed on the study purpose, test procedures, risks and benefits for participating. Ethical approval was sought and granted by the Human Research Ethics Committee (HREC) from the University of Cape Town (Appendix D) and Medical Research Council of Zimbabwe (Appendix Q) after obtaining institutional approvals from the relevant authorities (Appendix W, Appendix X) and schools headmasters (Appendix Y, Appendix AD, Appendix AE). Written informed consent (Appendix AF) and assent (Appendix AG) were obtained from parents and players respectively.

8.3.2 Procedure

All tests were conducted in the order described in Appendix AH in line with training-related activities. Prior to testing, all eligible participants were familiarised to the test battery items on two consecutive days. Participants either with self-reported injuries precluding physical activity [32] or who partook in multiple sports were excluded. However, injured participants competed in tests they were physically capable of performing. Participants also completed a brief questionnaire soliciting demographic and sport-related information. Data sought included age, sport played, school team, playing experience (number of years since starting training and playing rugby or cricket), number of hours of training per week, regular and alternative positions played, and playing status in the team. All this information had to be corroborated by the head coaches. A full description of SCRuM test battery is included in Chapter 7. Cricket players did not perform repeated high-intensity exercise (RHIE) and rugby-specific game skills due to high-school cricket coaches' reservations on performing rugby-oriented technical and physical skills.

Since reliability coefficients are population specific [32, 33], elite U16 and U19 rugby players were tested twice in a preliminary study to estimate the absolute and relative reliability of each SCRuM test item. Intraclass correlation coefficients and coefficient of variation for each test item have been presented in previous studies [29, 30]. Baseline data for these players was then compared to data obtained for U16 and U19 sub-elite and non-rugby players. Testing occurred in training during the rugby competitive season (May-August, 2018) for rugby players and cricket competitive season (September-November, 2018) for non-rugby athletes. This timing ensured that participants had gained match-related physical fitness [34, 35]. For each test, participants completed standardised warm-up procedures and were allowed three sub-maximal practice trials following test demonstration by the research assistants. Two trained research assistants conducted all the SCRuM tests, except for skinfolds and game-specific skills which were conducted by subject experts. Testing occurred on natural grass pitch for field tests and the gymnasium was used for strength-and-power based tests. Participants were requested to continue with normal diet and refrain from caffeine and performance enhancers during the testing period.

8.3.3 Statistical analyses

The Shapiro Wilk test assessed normality and Levene's test evaluated equality of error variances for dependent variables ($p<0.05$). The mean and standard deviation (Mean±SD) described parametric data. The chi-square test checked for significant differences in proportion for player compositions between elite and sub-elite rugby groups and age-categories. Two-way univariate analysis of variance (ANOVA) examined for significant main effect for fixed factors of age category (U16 vs. U19), playing standard (elite vs. sub-elite vs. non-rugby) and whether a significant age category×playing standard interaction existed. In case of significant main effect for playing standards, pairwise comparisons were assessed using Scheffé post-hoc test to locate mean differences. Additionally, identified significant interactions were followed with simple main effect analysis with Bonferroni correction adjusted for multiple comparison tests. Partial eta squared (η^2p) measured effect size and was interpreted as 0.01=small, 0.06=medium and 0.14=large [36-38]. All analysis were conducted using SPSS version 25.0 with statistical significance accepted when $p<0.05$.

8.4 Results

Descriptive data on age, playing experience and biological maturation are shown in Table 8-1. Significant differences between U16s and U19s were identified for chronological age, years from peak height velocity (YPHV) and playing experience. There were no significant differences within U16 age category across the playing standard for chronological age and playing experience. However, elite U16 rugby players reached biological maturity significantly earlier compared than sub-elite and non-rugby players. Within U19 age category, no significant differences were observed across playing standards for chronological age, playing experience and YPHV. With regards to player composition, all rugby groups had an equal proportion of forward and back players irrespective of age category [X^2 (df =1) =0.00, p=0.99] and playing standards [X^2 (df =1) =0.03, p=0.87]. The props and wingers were the majority in both U19 and U16 age categories.

Table 8-1: Sample demographics and sport-related information for participants (N=208)

Variable		U19 Elite	U19 Sub-elite	U19 Non-rugby	**All U19s**	U16 Elite	U16 Sub-elite	U16 Non-rugby	**All U16s**	*P(df=5)*
Sample size (*n*)		41	46	21	108	41	30	29	100	
*Age (yrs)		17.5±0.85	17.4±0.87	17.6±0.81	17.5±0.85	14.9±0.31	14.8±0.43	14.9±0.28	14.9±0.34	<0.001†
Age range (yrs)		15.6-18.9	15.7-18.8	15.4-18.9	15.4-18.9	14.4-15.3	13.9-15.3	14.4-15.3	13.9-15.3	
*YPHV (years)		1.93±0.53	1.64±0.97	1.78±0.56	1.78±0.76	0.64±0.92	-0.01±0.82	-0.05±0.61	0.24±0.87	<0.001†§
*Playing exp (yrs)		4.95±0.74	4.89±0.67	4.74±0.38	4.81±0.74	2.49±0.51	2.23±0.68	2.38±0.56	2.38±0.58	<0.001†
Generic positions	Forwards, n (%)	21(51.2)	23 (50.0)	-	44	20 (48.8)	16 (53.3)	-	36	
	Backs, n (%)	20 (48.8)	23 (50.0)	-	43	21 (51.2)	14 (46.7)	-	35	
	Allrounder, n (%)	-	-	10 (47.6)	-	-	-	11(37.9)	-	
	Batsman, n (%)	-	-	6 (28.6)	-	-	-	11(37.9)	-	
	Bowler, n (%)	-	-	3 (14.3)	-	-	-	5 (17.2)	-	
	Wicketkeeper, n (%)	-	-	2 (9.52)	-	-	-	2 (6.90)	-	
Specific positions	Props	7	6	-	13	6	5		11	
	Locks	5	7	-	12	3	4	-	7	
	Hookers	3	2	-	5	3	1	-	4	
	Flankers	5	5	-	10	6	4	-	10	
	Eighth man	1	3	-	4	2	2	-	4	
	Scrum half	4	3	-	7	6	3	-	9	
	Fly half	3	3	-	6	2	2	-	4	
	Centres	5	5	-	10	4	3	-	7	
	Wingers	4	9	-	13	7	4	-	11	
	Fullback	4	3	-	7	2	2	-	4	

*expressed as M±SD= mean± standard deviation; df=degrees of freedom for one way analysis of variance for between group effects; YPHV=years from peak height velocity indicating maturity offset years; n=number; yrs=years; playing exp=playing experience representing number of years playing sport in school either rugby or cricket; U=Under; Age-range=minimum year to maximum year; †all U19 groups significantly greater than all U16 groups (p<0.05); § Elite U16 significantly greater than U16 sub-elite and U16 non-rugby players (p<0.05).

Table 8-2 depicts mean and standard deviation (M±SD) scores for anthropometric variables, physiological characteristics and rugby-specific game skills at each age category according to playing standards.

Table 8-2: Characteristics of elite, sub-elite and non-rugby players by age category

	Under 19 (n=108)			Under 16 (n=100)		
Characteristic	Elite (n=41)	Sub-elite (n=46)	Non-rugby (n=21)	Elite (n=41)	Sub-Elite (n=30)	Non-rugby (n=29)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Anthropometrics						
Body mass (kg)	77.5± 9.58	75.9± 11.6	68.5±9.47	63.7 ±9.09	61.2 ±15.5	56.1± 7.83
Height (m)	1.73± 0.06	1.72± 0.08	1.71±0.06	1.67± 0.08	1.68 ±0.08	1.66 ±0.08
Biceps (mm)	6.71± 3.62	6.60± 3.14	6.57± 2.27	5.78 ±1.70	6.64 ±1.14	7.00± 3.91
Triceps (mm)	9.44± 2.95	9.83± 4.58	8.36 ±2.69	9.85 ±3.25	9.86 ±1.94	10.8± 5.89
Subscapular (mm)	12.8± 2.74	13.5 ±4.64	11.2 ±2.64	10.9 ±2.86	11.3± 2.70	12.5± 6.21
Suprailiac (mm)	8.93 ±3.84	9.51 ±3.93	9.52 ±1.98	8.28± 2.97	8.90± 2.99	9.97± 5.46
Abdomen (mm)	11.4 ±2.85	13.3 ±5.90	11.8± 2.41	11.4± 4.51	12.6 ±2.86	12.4± 6.34
Thigh (mm)	9.98± 2.48	11.0 ±4.83	9.08 ±2.00	10.7 ±3.84	11.4 ±2.29	11.7 ±4.40
Calf (mm)	5.49 ±1.03	6.11 ±2.07	6.17 ±1.29	6.49 ±1.55	7.72± 1.17	7.73 ±3.48
Sum of 7 skinfolds (mm)	64.7 ±15.6	69.8± 24.4	62.7± 11.6	63.4 ±17.1	68.4± 10.5	72.1± 33.1
Physiological tests						
20m speed (s)	3.25±0.17	3.36±0.23$^{\alpha}$	3.47 ±0.25	3.50 ±0.22	3.55± 0.22$^{\iota}$	3.63± 0.24
40m speed (s)	5.60 ±0.29	5.84 ±0.40$^{\alpha}$	6.10 ±0.27	6.14 ±0.46	6.20 ±0.60$^{\iota}$	6.47± 0.47
L-run (s)	6.21 ±0.32	6.33 ±0.33$^{\alpha}$	6.43 ±0.25	6.49 ±0.34	6.62± 0.46$^{\iota}$	6.67± 0.27
Vertical jump (cm)	47.8± 3.81	42.5± 3.84$^{\alpha}$	44.4± 3.85	38.3 ±2.38	34.9 ±2.82	32.6± 4.12
2kg MBCT (m)	9.23 ±1.26	8.31± 1.18	7.18 ±1.16	6.97± 0.64	5.91 ±0.86	5.83± 0.86
60s Push Up (n)	49.7 ±9.97	43.9 ±12.0	38.2± 6.50	38.4 ±10.1	35.6 ±8.90	32.6± 7.06
Wall sit leg strength (s)	146.0± 9.72	137.5 ±21.7	132.6 ±7.41	132.1± 6.61	123.3 ±13.0	121.2 ±23.0
Yo-Yo IRT (m)	1505.9±75.8	1443.6±259.1$^{\alpha}$	1053.3±148.8	1307.3±228.6	1030.7±269.6	897.9±171.7
1RM back squat (kg)	98.4 ±14.8	89.5± 16.3	-	-	-	-
Relative back squat	1.27±0.04	1.17±0.06	-	-	-	-
1RM bench press (kg)	90.5± 16.4	80.6 ±15.9	-	-	-	-
Relative bench press	1.16±0.08	1.06±0.06	-	-	-	-
RHIE 1st sprint test (s)	10.2±0.77	10.5±0.81$^{\alpha}$	-	-	-	-
RHIE 2nd sprint test (s)	13.0±1.02	13.2±0.96$^{\alpha}$	-	-	-	-
RHIE 3rd sprint test (s)	16.1±1.49	18.2±1.64$^{\alpha}$	-	-	-	-
RHIE total sprint test (s)	39.3 ±2.96	41.9 ±2.97$^{\alpha}$	-	-	-	-
Decrement in RHIE (s)	5.92±1.17	7.76±1.31$^{\alpha}$	-	-	-	-
Rugby-specific tests						
Tackling proficiency (%)	87.9± 8.44	84.8 ±8.16	-	83.0± 8.87	68.3±7.94	-
Passing ability (au)	116.2 ±2.13	113.0 ±4.07	-	105.9± 4.86	104.7±4.34	-

Running-and-catching ability	74.0 ±1.07	73.5± 1.35	-	71.7± 2.06	68.3± 2.56	-

Yo-Yo IRT= Yo-Yo intermittent recovery test; 1RM =one repetition maximum; RHIE=repeated high intensity exercise test measured in seconds; au =arbitrary units; α=sample size was 44; Decrement in RHIE denotes time differences between the first RHIE sprint and last 3rd sprint denoting fatigue time; ʅ=sample size was 26 for the respective tests. 2kg MBCT=2kg medicine ball chest throw.

Table 8-3 shows univariate test results for two-way ANOVA. Age category had a significant effect on all dependent variables except sum of seven skinfolds ($p=0.45$, $\eta^2p=0.003$). The largest mean differences in anthropometrical and test performances between U16s and U19s were shown for vertical jump (VJ) test ($\eta^2p=0.65$), passing ability skills test ($\eta^2p=0.58$) and 2-kg medicine ball chest throw ($\eta^2p=0.48$). For playing standard, there were significant main effects for all variables except for chronological age ($p=0.61$, $\eta^2p=0.01$), height ($p=0.40$, $\eta^2p=0.01$) and sum of seven skinfolds ($p=0.11$, $\eta^2p=0.02$). Post-hoc analysis revealed that elite and sub-elite rugby groups were significantly better compared to non-rugby players for 20-m speed ($p<0.001$, $\eta^2p=0.09$), 40-m speed ($p<0.001$, $\eta^2p=0.14$), 60-s push-up ($p<0.001$, $\eta^2p=0.11$) and WSLS ($p<0.001$, $\eta^2p=0.13$). However, L-run agility scores were significantly better in elite rugby players when compared to non-rugby players ($p=0.004$, $\eta^2p=0.06$). Vertical jump (VJ), 2-kg medicine ball chest throw (2-kg MBCT), Yo-Yo IRT L1, tackling proficiency, passing and running-and-catching ability tests improved significantly with increasing playing standards. However, there were significant interactions between age category and playing standard only for: VJ ($p=0.01$, $\eta^2p=0.05$), 2-kg MBCT ($p=0.01$, $\eta^2p=0.04$), Yo-Yo IRT L1 ($p=0.001$, $\eta^2p=0.07$), tackling proficiency ($p<0.001$, $\eta^2p=0.11$) and running-and-catching ability ($p<0.001$, $\eta^2p=0.14$).

Table 8-3: Two-way ANOVA results

Characteristic	Age-category				Playing standard				Age-category × playing standard		
	F	P	η^2p	Comparisons	F	P	η^2p	Pairwise	F	p	η^2p
Chronological age (years)	752.2	<0.001	0.79	U19s>U16s	0.50	0.61	0.01	-	0.08	0.92	0.00
Playing experience (years)	642.8	<0.001	0.76	U19s>U16s	4.20	0.02	0.04	E, SE>NR	3.77	0.03	0.04
YPHV (years)	201.2	<0.001	0.50	U19s>U16s	8.08	<0.001	0.07	E>NR	2.12	0.12	0.02
Anthropometrics											
Body mass (kg)	77.3	<0.001	0.28	U19s>U16s	9.23	<0.001	0.08	E, SE>NR	0.18	0.84	0.00
Height (m)	26.4	<0.001	0.12	U19s>U16s	0.92	0.40	0.01	-	0.26	0.77	0.00
Sum of skinfolds (mm)	0.56	0.45	0.00	-	2.26	0.11	0.02	-	0.45	0.63	0.00
Physiological tests											
20m speed test (s)	36.0	<0.001	0.16	U19s<U16s	9.61	<0.001	0.09	E, SE<NR	0.72	0.49	0.01
40m speed test (s)	51.1	<0.001	0.21	U19s<U16s	16.1	<0.001	0.14	E, SE<NR	1.02	0.36	0.01
L-run agility test (s)	31.0	<0.001	0.14	U19s<U16s	5.77	0.004	0.06	E<NR	0.10	0.91	0.00
Vertical jump test (cm)	369.3	<0.001	0.65	U19s>U16s	39.8	<0.001	0.28	E>SE>NR	5.13	0.01	0.05
2kg MBCT test (m)	185.4	<0.001	0.48	U19s>U16s	40.2	<0.001	0.29	E>SE>NR	4.39	0.01	0.04
60s Push Up test (n)	35.7	<0.001	0.15	U19s>U16s	12.4	<0.001	0.11	E, SE>NR	1.34	0.27	0.01
Wall sit length strength (s)	35.9	<0.001	0.15	U19s>U16s	11.3	<0.001	0.10	E, SE> NR	0.14	0.87	0.00
Yo-Yo IRT L1 (m)	73.4	<0.001	0.27	U19s>U16s	66.2	<0.001	0.40	E>SE>NR	7.31	<0.001	0.07
Game skills											
Tackling proficiency (%) †	62.0	<0.001	0.29	U19s>U16s	43.5	<0.001	0.22	E>SE	18.3	<0.001	0.11
Passing ability (au)†	210.4	<0.001	0.58	U19s>U16s	12.5	<0.001	0.08	E>SE	2.58	0.12	0.02
Running-and-catching ability (au)†	166.9	<0.001	0.52	U19s>U16s	46.7	<0.001	0.23	E>SE	25.1	<0.001	0.14

×Interaction; η^2p = partial eta squared; E=elite rugby players; SE=sub-elite rugby players; NR=non-rugby players; 2kg MBCT=2kg medicine ball chest throw; Yo-Yo IRT L1=Yo-Yo intermittent recovery test level 1; YPHV=years from peak height velocity representing maturity offset years; U19s=Under 19s; U16s=Under 16s; au=arbitrary units; †= 2*2 factorial ANOVA was conducted (age category=U19 vs. U16; Playing standard=elite vs. sub-elite); Pairwise=posthoc test results; One repetition maximum bench press and back squat tests, and repeated high intensity exercise performance ability test are removed from this analysis as there were performed only by U19 rugby athletes and can only be compared between U19 elite and U19 sub-elite; F= F statistic for ANOVA

Table 8-4 displays results for simple main effect analysis indicating mean differences between age-categories across each level of playing standard for dependent variables which showed significant interactions. Between age-categories, the largest mean differences in 2-kg MBCT scores (η^2p =0.34) (Figure 8-1), Yo-Yo IRT L1 test (η^2p=0.26) (Figure 8-2), running-and-catching ability (η^2p=0.50) (Figure 8-3) and tackling proficiency (η^2p=0.31) (Figure 8-4) were for sub-elite rugby players. However, non-rugby players showed the largest mean difference for VJ height (η^2p=0.43) (Figure 8-5).

Table 8-4: Results for the simple main effect analysis following significant interactions

SCRuM test variable	*Mean diff (95% CI)	Playing standard	Df	MS	F	P†	η^2p
Running-and-catching ability skill test (au)	2.27 (1.49-3.05)	Elite group	1	105.476	33.272	<0.000	0.18
	5.15 (4.32-5.97)	Sub-elite group	1	480.645	151.619	<0.000	0.50
Tackling proficiency test (%)	4.89 (1.22-8.54)	Elite group	1	487.8	6.94	<0.009	0.04
	16.5 (12.6-20.4)	Sub-elite group	1	4846.4	68.9	<0.000	0.31
Yo-Yo intermittent recovery test level 1 (m)	198.5 (168.3-288.7)	Elite group	1	808 043.9	18.8	<0.000	0.09
	413.0 (316.3-509.7)	Sub-elite group	1	3 042 135.7	70.9	<0.000	0.26
	155.4 (38.4-272.4)	Non-rugby group	1	294 145.5	6.86	0.01	0.03
2kg medicine ball chest throw test (m)	2.26 (1.81-2.71)	Elite group	1	104.7	99.6	<0.000	0.33
	2.41 (1.93-2.88)	Sub-elite group	1	105.1	100.4	<0.000	0.34
	1.34 (0.77-1.92)	Non-rugby group	1	22.0	21.0	<0.000	0.09
Vertical jump test (cm)	9.52 (7.99-11.0)	Elite group	1	1708.5	140.0	<0.000	0.41
	7.69 (6.05-9.32)	Sub-elite group	1	1053.9	86.2	<0.000	0.30
	11.8 (9.87-13.8)	Non-rugby group	1	1857.7	152.0	<0.000	0.43

*Mean diff=mean differences in the dependent variable between U19 and 16 (Under 19-Under 16) based on estimated marginal means; MS=Mean square; df=degree of freedom; †adjusted for multiple comparisons using Bonferroni correction; η^2_p=partial eta squared; F= each F tests the simple effects of Age category within each level combination of playing standard. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means; 95% CI=95% confidence interval for the mean difference.

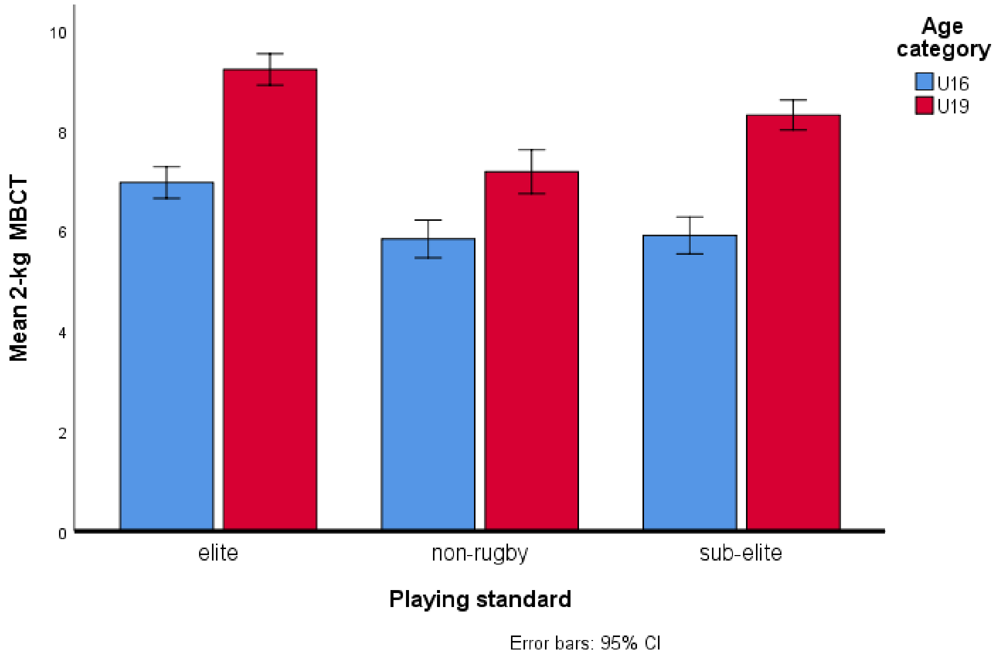

Figure 8-1: 2-kg MBCT across playing standard for each age category

There were significant mean differences ($p<0.05$) in test scores between the U19s and U16 for elite, sub-elite and non-rugby. For U16s, 2kg MBCT test showed good discriminative validity in differentiating elite from both sub-elite and non-rugby players but failed to distinguish sub-elite from non-rugby players. At U19 level, elite rugby players were significantly better than both sub-elite and non-rugby players, and sub-elite were also significantly better from non-rugby players. The largest mean differences between age categories were among the elite and sub-elite.

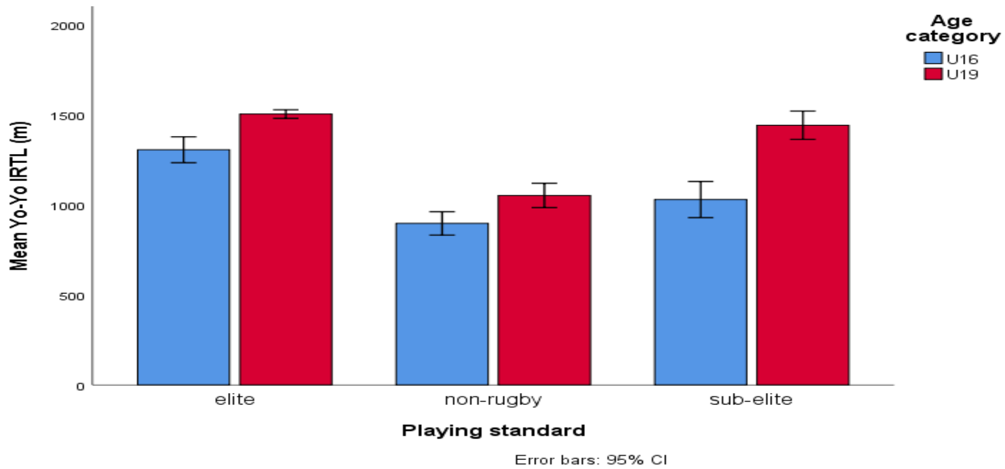

Figure 8-2: Yo-Yo IRT L1 across playing standards for each category

The Yo-Yo IRT L1 test scores significantly improved with increasing playing standard among U16s but failed to distinguish elite from sub-elite rugby players at U19 level. The sub-elite rugby players showed the largest mean differences between U19 and U16 athletes ($p<0.05$; $\eta^2_p=0.26$).

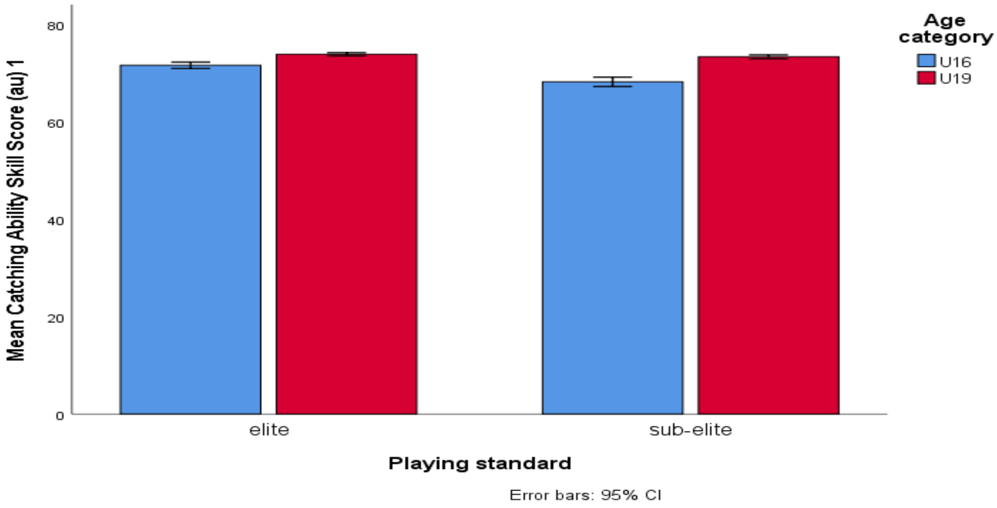

Figure 8-3: Running-and-catching ability scores across playing standard

Elite rugby players outperformed sub-elite rugby players at U16 level and at U19 level there were no significant differences. Greater mean changes between U19 and U16 were among sub-elite rugby players relative to the elite players.

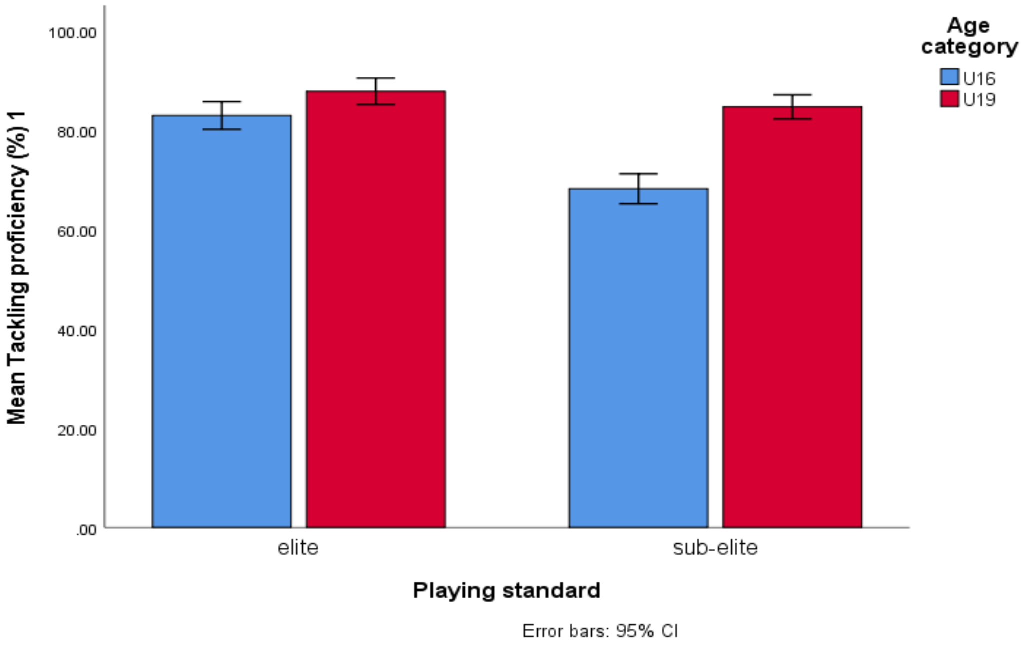

Figure 8-4: Comparison of elite and sub-elite rugby players for tackling proficiency

Elite rugby players significantly outperformed sub-elite rugby players at U16 level and at U19 level there were no significant differences. The sub-elite rugby players showed the largest mean differences between the age categories

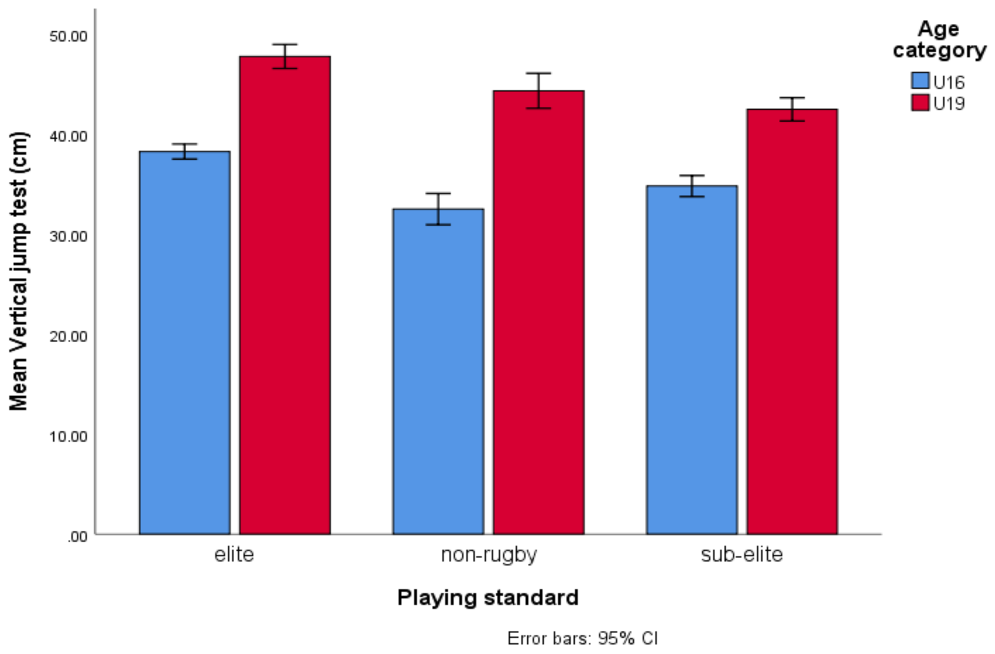

Figure 8-5: Vertical jump test scores

VJ effectively discriminated elite from both sub-elite and non-rugby players and concomitantly sub-elite from non-rugby players at U16 level. At U19 level, non-rugby players showed similar test scores to sub-elite rugby players. The largest mean differences between age categories were among the non-rugby players ($p<0.05$; $\eta 2p=0.43$).

8.5 Discussion

This study showed that age category had a significant main effect on all SCRuM test items except sum of seven skinfolds. An additional finding was the significant main effect of playing standard without interaction for body mass, 20-m and 40-m speed, L-run, 60-s push-up, WSLS and passing ability skill tests. However, significant interaction effects between age category and playing standard were observed only for VJ, 2-kg MBCT, Yo-Yo IRT L1, tackling proficiency and running-and-catching ability.

8.5.1 Influence of age-category

As hypothesised and consistent with previous studies [8-10, 20, 27, 34, 39-44], body mass, height, all physiological characteristics and game skills increased with age. These findings provide evidence on the relative sensitivity of these SCRuM test items in effectively discriminating younger rugby and non-rugby participants (U16s) from older adolescent rugby and non-rugby groups (U19s). Since U19s were significantly older compared to U16s in the present study, age-category differences in anthropometrical and test performances could be largely attributed to the normal processes related to growth and maturation that occur during the adolescent period [17, 38, 45, 46]. In the current study, U16s were, on average, commencing puberty (YPHV=0.24±0.87 years) whilst U19s players were approximately 2 years post-peak height velocity (YPHV=1.78±0.56 years). It is possible that the complex biological events that occur post puberty could explain the observed superior scores for the older participants. Changes in nervous and endocrine systems, muscle and bone morphology, and alterations in metabolism have been reported to be responsible for coordinating anthropometric and physiological alterations [47, 48]. Specifically, large increases in androgens (serum testosterone) concomitantly associated with proliferation of type 2 muscle fibres, muscle hypertrophy (especially in the thighs, calf, upper arms and chest), enhanced neuromuscular firing patterns, and changes in bone length (femur) could collectively explain the higher scores for body mass, stature, muscular upper-and-lower body muscular strength and power, endurance, agility, and speed for U19s [17, 49]. However, it is also possible that improvement in SCRuM test items with advancing age category could reflect differences in playing experience, training or a combination of the two [8, 42]. For the present study, U19s had significantly greater playing experience (proxy for training age) than U16s and included rugby groups with regular exposure to strength and power resistance training. Resistance training has been shown to increase resting testosterone levels, possibly contributing to the anabolic process during the adolescent growth spurt [47]. In addition, expected higher playing intensities with advancing age, exposure to longer matches (U16=60 minutes *vs*. U19=80 minutes) and training sessions (U16=10 hours/week *vs*. U19=15hrs/week) for U19 rugby participants may partly explain their superior physiological capacities and better rugby-specific game skills compared to their U16 counterparts.

The present study showed no significant differences for sum of seven skinfolds between U16s and U19s age categories. These findings are expected and comparable to related studies [8, 9, 11, 17, 45]. These results were observed despite the significant and large practical differences observed in chronological age, playing experience, biological maturity, body mass and height between U16s and U19s. This outcome probably suggests greater stability of skinfolds for schoolboy athletes with increasing age [19] thus dismissing the possible influence of age and the impact of growth processes on skinfold development after U16 age category.

8.5.2 Influence of playing standard

In contrast to the study hypothesis that elite rugby players would have a reduced sum of seven skinfolds by virtue of exposure to higher playing intensities, playing standard had no significant main effect on skinfolds. However, in support of these findings, Gabbett et al [18] also found no significant difference in the sum of seven skinfold thickness between elite and sub-elite players involved in competitive U16 RL. Till et al [37] also showed no differences among amateur, academy and professional junior RL players albeit at U13 level. A lack of difference in sum of skinfolds has previously been attributed to large interindividual variation within team squads of adolescent groups especially rugby [11], mainly due to the accommodative nature of the sport to all interested school children of various body sizes and shapes.

Although rugby players performed better than non-rugby players, possibly reflecting different speed requirements between rugby and cricket, the present study showed no significant difference in 20-m and 40-m speed tests between elite and sub-elite rugby players. These findings are consistent with previous studies [12] but also contradict others [43]. Speed is regularly listed as an important physiological characteristic in rugby, allowing for players to move fast in attack and defence and has been linked to match success and effective performance of game skills such as tackling [19, 27]. Lack of speed differences between rugby playing standards probably dismisses 20-m and 40-m sprinting abilities as important determinants of higher playing standards in Zimbabwe schoolboy rugby or shows its equal importance in both competitive leagues and the need for continued training. In addition, possible similar exposure to sprinting activities during training [12] and equal proportion of forward and back players in the rugby groups in this present study could also account for the lack of difference.

The modified L-run test failed to discriminate between elite and sub-elite rugby players, and also between sub-elite and non-rugby players. These findings were also shared by previous studies. Gabbett et al [50] showed that first and second grade rugby league players had similar L-run agility scores in professional senior players. Among U16 rugby league players, Gabbett et al [18] also showed no significant difference in agility scores using the 5-0-5 test between elite and sub-elite rugby league players. However, the 5-0-5 test utilised in the study by Gabbett et al [18] involved players performing a speed and agility shuttle run through timing gates. Till et al [37] also showed similar 5-0-5 agility test scores between academy and professional rugby league players for U13s, U14s, and U15s. Given the reported strong correlation between speed and agility [50], the lack of differences between elite and sub-elite in sprinting shown in the present study could account for the similar agility scores. The significant main effect of playing standard on agility shown in this study emanated from the test validity in differentiating elite players from non-rugby players. Similarly, Till et al [37] showed that professional rugby league players had superior agility test scores compared to the amateurs, however this was at U14 competitive level. A possible explanation for our finding could be observed differences in speed, playing experience and biological maturity between elite rugby players and non-rugby players.

Greater strength scores were observed for rugby players when compared to non-rugby players. However, there were no significant differences between elite and sub-elite rugby players for the 60-s push-up and WSLS strength tests. There are no studies to the authors' knowledge that have compared strength performances according to playing standard in junior RU using these tests. However, lack of differences in player composition, maturation, chronological age and playing experience probably explains similar findings for the upper-and-lower muscular strength between elite and sub-elite rugby players. An alternative explanation for the finding could be that these characteristics are equally important for all junior rugby players, irrespective of playing standards. However, when U19 rugby players were assessed for upper-and lower body muscular strength using 1RM BP and 1RM BS, respectively, the results showed a significant difference between the elite and sub-elite players for absolute and relative strength (Table 8.2). Consistently, Jones et al [12] showed that professional regional academy U18 RU players representing higher playing standard had superior bench press scores for upper body muscular strength than school-level players. Till et al [51] also showed that future professional players aged between U17 and U19 had heavier back squat scores when compared with the academy players. However, with the cross-sectional nature of the present study, it is not clear whether our results indicate that stronger U19 schoolboy rugby players are preferentially selected for the elite team resulting in higher measures, or there is increased volume of training muscle strength prevalent in the elite league facilitating greater development of the characteristic when compared to the sub-elite players. It is also possible that both factors could have contributed to this effect. Overall, the present study results expose the poor discriminative validity of both the 60-s push-up and WSLS in differentiating elite and sub-elite rugby players at the U19 level when compared to the 1RM BS and 1RM BP. It suffices, however, to recommend the use of 60-s push-up and WSLS when comparing rugby versus non-rugby players.

Few studies have compared junior rugby players across annual age-categories and playing at different competitive levels for passing ability technical proficiencies. Investigating the relationship between physical fitness and playing ability in rugby league players, Gabbett et al [23] assessed basic passing based on a skill criteria applied by expert rugby coaches. Similarly, this present study, with a modified passing ability test with eight technical elements for participant evaluation, showed that elite rugby players had superior passing skills compared to sub-elite rugby players. These findings are consistent with previous studies and reflect the importance of passing ability for the attainment of elite status in schoolboy rugby. Gabbett et al [23] showed that first grade rugby league player had better basic passing skills when compared to third grade players. These differences were attributed to the differences in age (23.7±4.3 years *vs*. 17.8±1.5 years), and playing experience (16.3±6.7 years *vs*. 9.4±4.3 years) between the first and third grade players. The present study showed no differences in age, maturity and playing experience between the elite and sub-elite rugby players negating the possible influence of these factors in accounting for the differences observed in the cohort of Zimbabwean schoolboy rugby players. However, with the higher level of proficiency expected in elite rugby and the important role of passing in rugby, it is possible to speculate that enhanced training of pass execution in elite competition is emphasised more than in sub-elite resulting in better passing ability. However, as a limitation, this study did not capture specific details with regards to the actual training content for game skills for rugby players. Future studies may investigate differences in training content by playing standards and see how that influences player performances on game skills such as passing.

8.5.3 Interaction effects

The Yo-Yo IRT L1 test scores improved with increasing playing standard among U16s but failed to distinguish elite from sub-elite rugby players at U19 level. These findings seem to suggest that endurance qualities have a greater impact in determining higher playing standards in U16 RU than in U19 RU. Possibly, increasing playing intensity at U19 level warrants rugby players regardless of playing standard to possess highly developed endurance qualities to cope with the intermittent high-intensity running episodes. However, simple main effect analysis showed greater cross-sectional differences between the age categories for Yo-Yo IRT L1 test scores among sub-elite rugby players. Cognisant of study limitations, these findings possibly indicate heightened endurance training or greater adherence to endurance training activities among U19 sub-elite players compared to U16 sub-elite players resulting in large performance differences between them. On the other hand, relatively small mean difference between U16s and U19s was observed for the elite group possibly suggesting robust early onset training of endurance in U16 elite players resulting in highly enduring players. Interestingly, young elite U16s (1307.3±228.6m) showed similar test performances with sub-elite U19 players (1443.6±259.1m) indicating that young elite rugby players are reaching older adolescent levels for prolonged high-intensity intermittent running ability faster.

At the U16 level, 2-kg MBCT test showed good discriminative validity in differentiating elite from both sub-elite and non-rugby players but failed to distinguish sub-elite from non-rugby players. However, at U19 level, the test effectively discriminated elite rugby players from both sub-elite and non-rugby players, and sub-elite from non-rugby players. With all groups having similar YPHV, age and playing experience, observed differences at U19 level could possibly be accounted for by differences in training strategies across playing standards. Collectively, these findings highlight increasing sensitivity of the 2-kg MBCT test with advancing age in discriminating rugby players by playing standards. Simple main effect analysis showed that larger cross-sectional performance changes in 2-kg MBCT scores between age-categories among rugby players compared to non-rugby players (Table 8.4). These findings allow for speculation of the importance of upper-body muscular power in rugby relative to cricket, especially among older U19 rugby participants and also hint at the likelihood of greater development with training in rugby regardless of competitive level. Muscular power is essential in rugby for effective tackles and to push opponents when needed [52].

VJ effectively discriminated elite from both sub-elite and non-rugby players and concomitantly sub-elite from non-rugby players at U16 level. However, this changed at U19 level with non-rugby players showing similar test scores to sub-elite rugby players. This happened because there were larger differences in VJ performances with increasing age category for the non-rugby players at U19 level relative to performance differences of other groups. Although the reasons for this are unclear given the cross-sectional design, it is possible to speculate that low physical fitness affect lower body muscular power production among late maturing U16 non-rugby players as evidenced by the low initial test scores relative to other groups. Given similar playing experiences across levels of playing standards at U16 age category, the possibility of specialist training of lower-body muscular power or preferential recruitment of powerful U16 players in the elite and sub-elite rugby groups could explain the relatively higher VJ scores for the rugby players. However, training probably emphasising motor activities such as sprinting and jumping activities that required the production of significant lower-body muscular power could account for the larger performance changes shown by older non-rugby players. These findings may also suggest that elite cricket players may overcome maturational, playing experience and physical fitness disadvantages at U16 level, and develop lower-body muscular power needed for running and jumping for aerial balls to the point of matching sub-elite rugby players with advancing age [37]. Previous longitudinal studies have hinted on relatively weaker athletes having a greater capacity for improvement with advancing age than highly trained athletes [24].

The present study showed a significant interaction between the effects of age-category and playing standard on tackling proficiency and running-and-catching ability. For both tackling and catching, elite rugby players outperformed sub-elite rugby players at U16 level probably suggesting increased sensitivity of these game specific skills in discriminating younger rugby players by playing standards at that level. However, this changed at U19 level with both groups showing no significant differences for both performances, findings which dismiss the usefulness of these skills in differentiating older adolescent rugby players by playing standards. Therefore, between U16s and U19s, large differences in the performances of these tests were in sub-elite rugby players compared to the elite rugby players and were shown more for the tackling proficiency test. The reasons for these findings are unclear given the observational nature of the present study and require further testing in future studies. The low initial performances of sub-elite U16 rugby players relative to elite U16 rugby players possibly reflecting poor training or less proficiency in skill execution especially for tackling could account for the large performance gaps between U16s and U19s for the sub-elite group. Alternatively, greater adaptation to training for tackling and catching with increasing age, maturity, playing experience and playing intensity among sub-elite players could also explain the seemingly better performances at U19 level. For tackling, it seems that elite U16 rugby players reach top level scores early as evidenced by relatively small mean differences with the elite U19 rugby group. These findings probably indicate that young elite U16 rugby players reach mature level scores for tackling early than sub-elite rugby players suggesting either greater proficiency or less adaption to training in elite players than in sub-elite rugby players.

8.5.4 Study limitations

Novelty in the current study was highlighted by comparing elite, sub-elite and non-rugby players at U16 and U19 age-categories from a country hardly known for dominating international rugby events. However, this study is not without limitations and the study results should be interpreted cautiously in light of these limitations.

- The study involved purposive selection of single schools to represent each playing standard and included only U16s and U19s to represent young and older adolescent athletes. This sample may not have been representative of all age-categories and the multiple schools competing in the SESRL, CESRL and cricket interscholastic competitions in the country. The anthropometric, physiological and game skills are likely to differ with chronological age, schools, training strategies, player selection criteria, and player motivation and coaching philosophies possibly over-or under-estimating the fitness, body composition or skills of junior elite and sub-elite players [53]. This limits the external validity of study results to other schools not involved in the study and also to other age-categories not assessed in this study.

- Given the complexity and multifaceted nature of the sport of rugby, only examining the anthropometric, physiological and game specific skills is a possible limitation and a more holistic protocol including tactical, perceptual-cognitive skills and psychological measures would have been ideal to comprehensively understand and identify qualities or skills discriminating players of different ages and playing standards [37]. A recent study showed that psychological attributes such as players' attitudes and personality traits, mental strength and emotional stability are key qualities that coaches consider in good adolescent rugby players and in player recruitment for TID initiatives [54]. Further studies objectively assessing these qualities and how they differ with age and playing standards in junior rugby are warranted.

- The cross-sectional nature of the study lacked analysis over an extended period of time [38]. This design ignores the dynamic nature of player development possibly narrowing the usefulness of the data for TID [55]. However, the data are crucial for hypothesis generation which could be further tested in future prospective cohort studies. Also, the sample size was limited to allow for the categorisation of participants by player positions.

8.6 Conclusion

This is the first Zimbabwean study to compare anthropometric, physiological characteristics and rugby-specific game skills of schoolboy rugby players (including non-rugby players as a comparative group) of different age categories and playing standards. All anthropometric, physiological characteristics and game skills progressively increased with age except for sum of seven skinfolds suggesting large influence of age and maturity-related factors on attribute development among schoolboy athletes. With regards to playing standards, upper-and-lower-body muscular power, prolonged high intensity intermittent running ability, tackling, passing, running-and-catching ability improved with increasing playing standards. However, there were significant interactions between the effects of age category and playing standard for upper-and-lower-body muscular power, prolonged high intensity intermittent running ability, tackling and catching. These findings suggest that, for these variables, the discriminative ability for playing standard is dependent on age category. Yo-Yo IRT L1, VJ, tackling and catching tests demonstrated greater discriminative ability among U16s than in U19s whilst the 2-kg MBCT test showed the converse. From a practical perspective, Yo-Yo IRT L1, VJ, tackling and catching tests could be used as screening tests for talent search in young rugby players whilst the 2-kg MBCT test is sensitive in differentiating older male adolescent players by playing standards.

8.7 References

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9 CHAPTER 9: CONCLUSION AND RECOMMENDATIONS

9.1 Summary of the key study findings

The purpose of this study was to determine the qualities and/or skills defining "good" male adolescent rugby players in Zimbabwe. The absence of a universally-agreed test battery for profiling young male adolescent rugby players in the literature justified sequentially-developing the School Clinical Rugby Measure (SCRuM) test battery composed of face-and-content validated, practically feasible and reliable tests for anthropometric, physiological characteristics and rugby-specific game skills. Following development, the ultimate aim was identifying component SCRuM test items capable of discriminating schoolboy players of different playing standards (elite *vs.* sub-elite *vs.* non-rugby) and age categories (U16 *vs.* U19).

Appendix AI shows the different versions of the SCRuM test battery developed per each stage of the study. Phase I led to the development of the first version of the SCRuM test battery based on a collection of findings from (i) a narrative literature review (Chapter 2), (ii) a qualitative study (Chapter 3) and, (iii) two systematic reviews (Chapter 4 and Chapter 5). The findings from the literature review revealed the multi-dimensional nature of anthropometric characteristics, physiological qualities and rugby-specific skills important in the sport of rugby regardless of competitive level or age category. In addition to the physical characteristics and rugby-specific game skills, the qualitative study further revealed the influence of psychological attributes such as emotional stability, mental strength, and personality traits in defining good male adolescent rugby players as perceived by the rugby coaches. Based on these findings, it is recommended that future test batteries profiling young male adolescent rugby players incorporate objective tests for the assessment or screening of psychological qualities such as mental strength and emotional stability. Furthermore, future studies should also examine the discriminant validity of these psychological attributes in distinguishing rugby players of different playing standards and age categories. The second qualitative study (Appendix C) also showed that playing rugby for Zimbabwean high school students is a choice largely influenced by both intrinsic (personal preference, enjoyment, and nature of the sport) or extrinsic factors (influence from significant others, professional ambitions, emulation and monetary rewards). These findings suggest that to effectively promote competitive rugby participation among schoolboys more recognition should be paid to factors motivating schoolboys to participate in competitive rugby. For example, reputable senior professional rugby players could be invited to lead TID initiatives, together with the coaches, providing the extrinsic motivation to potential junior rugby players for participation in schoolboy competitive rugby. However, coaches perceived players' characteristics (performance during training, attitude, physical qualities and skills) and match-related factors (impending competitive match) as key strategies for selecting schoolboys for possible inclusion in school rugby teams. These findings seem to highlight the complexity and multiplicity of factors involved in selecting schoolchildren who participate in competitive school rugby teams. But these findings re-emphasise the importance of psychological attributes and the possession of commensurate physical or technical skills. Hence, these findings further support the need for a holistic approach in investigating the qualities or skills defining young male adolescent rugby players in future studies incorporating psychological attributes and outcome measures for training performances.

The systematic review revealed several studies that examined the physiological characteristics and game skills of rugby players. The interest could be linked with suggestions that success in rugby is highly dependent on physiological characteristics and proficiencies in technical skills [1-3]. Unlike for rugby-specific game skills, each physiological construct identified in the literature had multiple tests for measurement with variable evidence of measurement properties. Both systematic reviews also revealed lack of high-quality studies with suitable sample sizes based on the COSMIN checklist for the assessment of the psychometric properties of the physiological and rugby-specific game skills tests used. This raised questions about the usefulness and applicability of the current tests in rugby and created a need for continued high-quality studies evaluating the measurement properties of these tests among rugby players with large sample sizes ($n \geq 50$). Indirectly, the current study was an attempt to evaluate the reliability and construct validity of common and modified adopted rugby tests using a relatively larger sample size than reported in most studies.

Thereafter, the test battery was subjected to further refinement through face-and-content validation processes involving key informants and rugby experts (Chapter 6) leading to the development of second, third and fourth version of the test battery. Results from the face and logical validity studies revealed that the following variables were relevant to be included in the SCRuM test battery: anthropometric qualities (weight, height), physiological characteristics (speed, repeated high-intensity exercise performance ability, prolonged high-intensity intermittent running ability/endurance, change of direction speed/agility, anaerobic capacity, upper and lower-body muscular power and strength, muscular flexibility), and rugby-specific game skills (reactive agility, passing-for-accuracy, tackling proficiency, and catching). Subsequently, the practical feasibility of implementing each of the test items in the fourth version of the SCRuM test battery in the local context was evaluated by high school rugby coaches producing the fifth version (Chapter 6). In that study, proposed tests for lower-and-upper body strength (1-RM BS and 1-RM BP) were reported to have low practical feasibility mainly because of the weightlifting restrictions imposed for young U16 high school athletes in the country. Coaches expressed concerns about the type of equipment needed, the cost of the equipment, and safety concerns for schoolboy rugby players. Suggestions included the need to incorporate new tests in the SCRuM test battery which are cost effective for the assessment of lower and upper body strength among U16 young rugby players in the Zimbabwean setting. These concerns were, however, not shared for the older U19 male adolescent rugby players because of regular exposure to strength and power training.

In the first part of Phase III, the fifth version of the test battery was then assessed for test-retest reliability of the component test items using elite U16s and U19s (Chapter 7). Regardless of age category, good to excellent ICCs were shown for all anthropometric variables. The tests for physiological characteristics and game skills administered to U19 male adolescent rugby players which showed good to excellent relative reliability and acceptable absolute reliability included: 20-m speed, 40-m speed, L-run, VJ, 60-s push-up, 2-kg MBCT, WSLS, RHIE, 1-RM BS, 1-RM BP, Yo-Yo IRT L1, tackling, passing ability and running-and-catching ability test. Among U16 players, 10-m speed, 20-m speed, 40-m speed, L-run, VJ, 60-s push-up, SR, 2-kg MBCT, WSLS, Yo-Yo IRT L1, tackling, passing ability and running-and-catching ability test also had acceptable reliability values.

The second part of Phase III (Chapter 8) constituted as the main study and established the discriminative ability of the SCRuM test items in sixth version in differentiating schoolboy athletes across three proficiency levels. This involved a comparative analysis of anthropometrical and test performances for elite male adolescent rugby players, sub-elite male adolescent rugby players and elite male non-rugby players playing competitive schoolboy cricket for the U16 and U19 school teams. The first hypothesis was that elite male adolescent rugby players would have significantly better test scores compared to both sub-elite rugby players and non-rugby cricket players regardless of age category (U16 or U19), and, concomitantly, sub-elite rugby players would show significantly better scores than the non-rugby players. Regardless of playing standard, the second hypothesis was that older (U19) male adolescent players would have significantly higher SCRuM test item scores compared to younger (U16) male players except for the skinfold measurement. The third hypothesis was that there will be significant interaction between the effects of age and playing standard on the discriminative abilities of anthropometrical and test performances.

Of all the variables in the sixth version of the SCRuM test battery, this study showed a combination of six physiological variables and three rugby-specific game skills defining the general qualities and skills of good male adolescent rugby players in Zimbabwe. Although all the SCRuM variables showed improvement with advancing age, this study specifically showed that the discriminative abilities for these nine attributes by playing standards were age-dependent. The Yo-Yo IRT L1, VJ test, tackling proficiency test and running-and-catching ability test showed greater discriminative abilities for playing standards among U16s (See Supplementary file 2 and See Supplementary file 3). These findings imply that lower-body muscular power, prolonged high-intensity intermittent running ability/endurance, tackling and catching abilities effectively discriminates Zimbabwean elite U16 male adolescent rugby players from U16 sub-elite and non-rugby players, and further differentiates sub-elite male adolescent rugby players from non-rugby male adolescent cricket players. A greater discussion of these findings relative to the findings of other studies is found separately in a published paper (see Appendix AJ). The paper also presents raw scores for the elite U16 Zimbabwean rugby in comparison with elite players of similar age groups from other countries, showing relatively lower values for the Zimbabwean cohort for most of the SCRuM variables.

For the older U19 male adolescents, the 40-m speed test, 2-kg MBCT, 1-RM BP test, 1-RM BS test, RHIE test, and passing skill ability test showed better discriminative capabilities by playing standard among U19s (See Supplementary file 1 and See Supplementary file 3). These findings suggest that 40-m sprinting ability, upper-body muscular power, upper-and-lower muscular strength, repeated high-intensity exercise performance ability, and passing skill ability effectively discriminates Zimbabwean elite U19 male adolescent rugby players from U19 sub-elite and non-rugby players, and further differentiates sub-elite male adolescent rugby players from non-rugby male adolescent cricket players. A greater discussion of these findings is found separately in a published paper (see Appendix AK).

9.2 Result implications and recommendations

9.2.1 Training implications

Given that U19 players showed superior scores for most of the SCRuM test items compared to U16 players, rugby coaches at the U16 level may consider implementing a myriad of training interventions oriented around increasing players lean body mass, upper-and-lower body muscular strength and power, muscle flexibility, agility, speed, endurance, tackling proficiency, passing and catching ability skills. This may be important in improving the developmental transition of U16 players to the U19 level and in minimising performance differences between age groups. From a practical perspective, the Yo-Yo IRT L1, VJ, tackling proficiency and running-and-catching ability tests could be used in TID initiatives for screening potentially talented young U16 rugby players. Hence, there is need for continual training of prolonged high-intensity intermittent running ability, lower-body muscular power, tackling and catching ability of young U16 rugby players as these qualities or skills are linked to higher playing standard and define the attributes of good U16 male rugby players. In addition, selection of talented and skilled U19 rugby players should be based on players’ performances on the 2-kg MBCT, 40m sprinting ability test, RHIE test, 1-RM BP and BS tests and passing skill abilities.

These findings can guide and inform the objective recruitment of potentially talented sub-elite and non-rugby players during school-based or nationwide TID programmes. With subsequent establishment of normative data or references for SCRuM test items among young male adolescent rugby players, subjective recruitment of potential players can now be partly replaced by objective and specific screening of rugby talent based on evidence of qualities capable of discriminating rugby players of different playing standards.

9.2.2 Future research

This study provides a baseline for further evaluation of U16 or U19 schoolboy rugby players in Zimbabwe playing at different levels of competition. Future research can longitudinally track elite or sub-elite young male rugby players and establish the evolvement of physiological characteristics and rugby-specific game skills with time. There is still need for further large robust studies incorporating other age categories from U13 to U19 to fully understand the qualities or skills defining all adolescents at each of these distinct age categories. Normative values for each identified attribute defining good adolescent rugby players are needed for the relative comparisons of Zimbabwean players with other schoolboy rugby players from other countries and also to benchmark test performances during TID programmes. Given the established good reliability and proven construct validity of many SCRuM test items, further studies examining the criterion validity of the SCRuM tests in male youth rugby players are necessary. In addition, there is need for future studies to relate the identified qualities or skills making a good adolescent rugby player to injury risk to understand the qualities that “break” good adolescent rugby players and predict injury risk among young Zimbabwean cohort of elite and sub-elite rugby players. Future studies also relating the identified qualities or skills defining good male adolescent rugby players with match success or playing performance are needed in young rugby players are needed.

9.3 Critique of the study methodology

9.3.1 Strengths of the study

This is the first Zimbabwean study to compare the anthropometric, physiological characteristics and rugby-specific game skills of schoolboy rugby players (including non-rugby players as a comparative group) of different age categories and playing standards. Due to the lack of consensus in the literature on the variables and corresponding tests to include in a test battery profiling young rugby players, this study sequentially assembled the SCRuM test battery based on narrative literature findings, qualitative opinions from local rugby coaches, and evidence from two systematic reviews. Further refinement of the test battery was conducted through evaluating the face validity, logical validity, practical feasibility and test item reliability. All this developmental process ensured that the composition of the SCRuM test battery had all the relevant variables (based on the literature and systematic review findings, rugby coaches, local and international rugby experts) which were also practically implementable in the local setting.

Globally, previous studies in RU and RL have either compared elite male adolescent players of distinct age categories playing rugby in countries of different playing abilities or elite male adolescent rugby players of different age categories in an attempt to understand performance differences between playing standards and across age categories [4-9]. Uniquely, the current study compared a relatively larger sample of elite rugby players with sub-elite and non-rugby players for anthropometric and test performances. The justification for including elite schoolboy cricket players involved incorporating a second comparative group of schoolboy athletes playing a competitive sport known to have different physical and technical demands to rugby [10]. This methodology enabled understanding of the general qualities or skills needed by rugby players when compared to age-matched non-rugby players and the specific qualities or skill discriminating elite from sub-elite rugby players.

9.3.2 Limitations of the study

This study had some limitations that need consideration when interpreting obtained results. The majority of the study limitations have been elaborated in the previous chapters.

Qualitative study: Briefly, the qualitative study showed that local rugby coaches perceived physiological, anthropometric, and psychological and game-specific skills to be defining good male adolescent rugby players. However, the findings should be interpreted with caution because they reflect coaches' perspectives and not the opinions of participating schoolboy rugby players who could have given similar or different first-hand information on the qualities or skills important for them to be good rugby players. In light of resource constraints in the local context, rugby coaches perform multi-dimensional roles in school rugby teams such as recruiters, selectors, mentors, and trainers equally positioning them to comment on the qualities or skills defining good male adolescent by virtue of experience. Nevertheless, future studies may triangulate coaches' perceptions with the opinions and impressions of participating schoolboy rugby players. In addition, it is possible that the heterogeneity in coaching backgrounds and current employment of the coaches utilised in the study could have moderated their responses because of the differences in the level of coaching of schoolboys. It is undoubtedly possible that coaches from the amateur schools could have reflected on the questions from the interview guide much less given their less expertise than coaches from the elite and sub-elite leagues, thereby diluting the responses on the qualities or skills defining good male adolescent players. It was also important to explore the qualities or skills coaches consider least important and derive the reasons for the exclusion of highlighted qualities or skills.

Systematic reviews: Important limitations were identified regarding the systematic review studies. Currently, there are no published reviews investigating measurement properties of performance-based tests measuring physiological characteristics and game skills in rugby. This renders comparisons with other review studies impossible. Furthermore, the inclusion criteria only considered full-text peer reviewed articles and completely excluded grey literature, possibly missing out on important information on the tests commonly used in literature and their measurement properties. Although the COSMIN has been developed for the evaluation of measurement properties and has been generally used in the literature for that purpose, the guidelines appear well-suited and more applicable for appraising the quality of questionnaire-based studies. In the context of performance-based tests such as used in rugby, the applicability of the COSMIN as a quality rating tool for the studies on measurement properties still requires careful consideration. It should also be noted that most articles included in the review studies assessed RL players. This can partly be explained by the relatively high amount of studies by Gabbett et al. This could have biased the results for the systematic review towards tests that are more focused on RL.

Face validity, logical validity and practical feasibility study: The approach used for face and logical validation of the test battery can be criticised due to its potential for subjective and cognitive bias from the experts thereby influencing the validity of the results. However, attempts were made to draw experts from various countries for the different experiences. Eight (8) international and twelve (12) local rugby experts were used for the logical validity study. Nevertheless, it is possible that the content of the SCRuM test battery could have differed if different experts had been chosen. Achieving appropriate sample size and retaining experts in subsequent rounds was problematic with the logical validity study. Of the 63 experts invited, 20 and 9 participants participated in the first and second round, respectively. Therefore, the results reflect the opinions of experts who timeously responded and were willing to participate in the study. Nonetheless, all the experts were recruited based on expertise in the sport of rugby working in various capacities. Another limitation was that experts judged the relevance of performance measures for inclusion in the SCRuM test battery based only on anthropometric, physiological characteristics and rugby specific game skills. Due to the complexity of the sport, there are however several other factors, for example, sociological, psychological, perceptual and cognitive skills such as decision making ability, anticipation, tactical awareness which may influence playing performance [11] and may be important to include in test batteries for profiling and comparing young rugby players. Feasibility study results reflected the opinions of local rugby coaches used in the study considering the contextual resources available at the various schools that were selected. For example, U16s and below age categories [U13-U15] are not allowed to weight train or participate in resistance gym training as a policy in Zimbabwe because of their age to protect them from musculoskeletal issues possibly resulting from mainly unsupervised resistance weightlifting. Hence, in the present study, proposed tests for lower and upper body strength had low practical feasibility mainly because of the weightlifting restrictions imposed for young high school athletes in the country. Coaches had concerns on a number of feasibility parameters such as the type of equipment needed, the cost of the equipment, safety concerns, and age-specificity of the test with regards to these weightlifting tests. The subjective nature of the data gathered may cover major practical feasibility issues which can become apparent during the implementation phase of the study.

Therefore, there was need to assess other focus areas of feasibility besides practicality and acceptability issues.

Test-retest reliability study: We chose a pragmatic approach to evaluate the reliability of the test items by conducting the study during the competitive season. That could have affected participant optimal performance secondary to acute fatigue effects from training, competitive matches and testing. During the test-retest study, no attempts were made to standardise the timing, type and quantity of food/fluid intake, wind speed and air resistance. All of this may impact on test performances across trials.

Construct validity study: A further limitation of the present study was cross-sectional examination of players representing two age categories conveniently-derived from selected schools. This limits generalisability of the study findings to other age-groups and to rest of the schoolboy rugby players playing RU in Zimbabwe. Future studies in this area of research may aim to compare playing at a broader range of age categories or include a large random sample from various schools team playing in the SESRL and CESRL. In addition, the sample size was small to allow for player position categorisation. Participant testing was conducted during the rugby and cricket competitive season during training hours. The possible influence of residual fatigue may have influenced the cross-sectional test performances. However, an attempt was made to intersperse with 48 hours the performance of the most physically demanding tests. The SCRuM test battery only had anthropometric, physiological and coach-rated rugby skills in its multi-dimensional attempt, however a more holistic test battery encompassing all the elements important in rugby such as technical, tactical and psychological measures would have been appropriate. Regardless, since our data did not describe specific details on training, we cannot exclude other factors (e.g. better coaching, training content, use of nutritional and ergogenic substances, training intensity, and innate abilities) could also explain some of the observed differences between elite, sub-elite and non-rugby players found in the study. However, given the documented importance of tackling and catching ability in senior professional and schoolboy rugby circles, future studies modifying the test procedures for tackling proficiency test and running-and-catching ability test are warranted to better discriminate U19 rugby players by playing standards. Possibly, the addition of components of reaction or decision making in the skills test procedures would improve their level of difficulty and effectively become useful at U19 level to differentiate older adolescents by playing standards among Zimbabwean schoolboy players. The factorial ANOVA approach utilised in the current study involved running many separate comparisons where the independent variable was categorical (e.g. elite *vs* non elite) and each of the SCRuM test items acting as the dependent variables. However, this approach made it more difficult to account for collinearity between the tests. Further analysis involving flipping the outcomes to make them predictors within a multivariate regression model, where the focus is on predicting group membership (e.g. elite *vs* non elite) would be needed. This represents a more flexible and logical model, which would help to streamline to a more parsimonious predictive model, controlling for collinearity and redundancy, and therefore highlighting the variables (tests) most associated with elite status or not.

9.4 Conclusion

Cognisant of the study limitations, this thesis contributes to the body of knowledge by presenting the qualities or skills contained in the SCRuM test battery linked to higher playing standards for U16 and U19 male adolescent rugby players playing competitive rugby in low-resource settings such as Zimbabwe. Briefly, this study showed that the attributes defining good (discriminative by playing standards) male adolescent rugby players are age-dependent and range from physiological characteristics to game skills (Table 9-1). Specifically, the U16 adolescent rugby players require high levels of prolonged high-intensity intermittent running ability, lower-body muscular power, tackling proficiency and running-and-catching ability to achieve higher playing standards, whereas elite U19 male adolescent rugby require upper-body muscular power, upper-and-lower-body muscular strength, 40m sprinting ability, repeated high-intensity exercise performance ability, and passing ability. Both researchers and coaches can use the current findings as foci points for long-term junior rugby training and development programmes ensuring the attainment of elite status by sub-elite players at distinct age categories. These results hint to junior rugby coaches on the qualities or skills possibly important for U16/U19 team or squad selection, and sports physiotherapists working with U16/U19 school rugby teams during the designing of rehabilitation intervention and training programmes following injury. However, given the reported importance of skills such as tackling and catching, future studies modifying the test procedures for tackling proficiency test and running-and-catching ability test are warranted for the tests to better discriminate U19 schoolboy rugby players by playing standards.

Table 9-1: Final SCRuM test items per age category

Age category	SCRuM test item	Physiological quality or skill assessed
U19s	40m-speed test	40m sprinting ability
	2 kg Medicine Ball Chest Throw test	Upper-body muscular power
	1RM Bench Press test	Upper-body muscular strength
	1RM Back Squat	Lower-body muscular strength
	Repeated High-Intensity Exercise test	Repeated high intensity exercise performance ability/Anaerobic capacity
	Passing ability skill test	Passing
U16s	Vertical Jump test	Lower-body muscular power
	Yo-Yo Intermittent Recovery Test Level 1	Prolonged high-intensity intermittent running ability/Endurance
	Tackling proficiency test	Tackling
	Running-and-catching ability test	Catching ability

9.5 References

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10 APPENDICES

Appendix A: Key findings on match demands

Authors	Methods of analysis	Sample	Movement/Variable assessed	Results
Deutsch et al [45]	Heart rate (HR) Blood lactate (BL) concentration levels. Time Motion Analysis (TMA).	24 U19 elite rugby players (18.4±0.5years) Players classified as: FRF (n=6 players) BRF (n=6 players) IB (n=6 players) OB (n=6 players) Forwards (n=12) Backs (n=12)	Locomotion Standing still Walking Jogging Utility movements Cruising √ Sprinting √ Static exertion Rucking √ Mauling √ Scrummaging √	% time in high-intensity activities (FRF=58.4%; BRF=56.2%; IB=40.5%; OB=33.9%). Time spent in low-and-high intensity activities=15% vs. 85%. Mean lactate concentration= No significant difference between groups Maximum distances (FRF=4400±398m; BRF=4080±363m; IB=5530±337m; OB=5750±405m. Backs covered significant distance (5640m vs. 4240m) Forwards spent significant time standing still (46% vs 39%). Distance in utility, cruising and sprinting=Backs covered more than forwards. Mean single sprint distance=No significant difference between groups. Distance jogging=Forwards covered more. Mean distance walked by backs was higher (1700m vs. 996m) than forwards. % time spent in rucks and mauls = forwards spent more than backs (9.3% vs. 1.4%). Time spent in high intensity work=forwards spent more (11.3min vs. 3.6min) Work to rest ratio (Forwards=1:1.4 vs. Backs=1:2.7
Duthie et al [57]	TMA.	47 Super 12 elite rugby players Players classified as: FRF (n=16 players) BRF (n=15 players) IB= (n=9 players)	Locomotion Standing Walking Jogging Striding √ Sprinting √ Static exertion	Total time spent (min:s) Standing= no significant difference between forwards and backs Walking= backs > forwards (33.15±8.23 vs. 23:46±5:47) significant difference Jogging= backs < forwards (13:60±3.43 vs. 14.50±2.48) significant difference

		OB= (n=7 players) Forwards (n=31) Backs (n=16)	Scrums √ Rucks √ Mauls √ <u>Other</u> Jumping √ Lifting √ Tackling √	Striding=no significant difference between forwards and backs Sprinting=backs> forwards (1:18±0.29 vs. 0.27±0.23) significant difference Static exertion=forwards> backs (9.06±2.48 vs. 1.19±0.43) significant difference Work= forwards > backs (12:22±3.49 vs. 4.51±1.16) significant difference Greater total work in forwards compared to backs Most work periods lasted less than 4seconds and rest periods 20seconds.
Eaton and George [59]	TMA using the Prozone system.	35elite rugby players. Age range (20-34) years <u>Players grouped as</u> Props Hooker Lock Loose forward Scrum half Inside backs (IB) Outside backs (OB)	<u>Low intensity (LI) activities</u> Jogging (> $2ms^{-1}$) Walking (>$0.5ms^{-1}$) Standing (<$0.5ms^{-1}$) <u>High intensity (HI) activities</u> Sprinting (> $7ms^{-1}$) High speed runs (> $5.5ms^{-1}$) Running (>$4ms^{-1}$) <u>Non-running HI activities</u> Scrums Rucks/Mauls Tackling Lineouts	Sprinting=OB performed largest number of sprints over longest average distance, props had the least High speed runs= scrum halves had the highest speed runs, props the least. Scrums=average quantity/match (29±6) Rucks/mauls=forwards performed significantly more than backs (p<0.001). Hookers completed the most, OB the least. Tackling=frequency of being tackled not significant difference between position. All positions involved in tackling. Lineouts=props performed the greatest number of lifts; locks had the highest number of jumps/game. Total HI=forwards spent significant amount of time in HI activities than backs (p<0.05). Loose forwards had more time in HI, OB performed the least HI activities Jogging=hookers performed the most, smallest number performed by props. Walking=most frequent LI activity engaged by all players. OB walked the furthest; locks the least Standing=all back players stood less than forwards.
Duthie et al [65]	TMA	28 Super 12 elite rugby players. <u>Players categorised as:</u> Forwards (n=10) Backs (n=7)	<u>Variables</u> Duration of sprints Velocity attained	A total of 503 sprints in 10 Super 12 games were analysed. Forwards, backs performed 215 (43%), 288 (57%) of the sprints, respectively. Forwards performed 13± 6 sprints per game, which was 11±6 (*p*< 0.01) fewer than for the backs (24± 7). The mean duration of sprints for the forwards (2.5±

				1.6 seconds) was 0.7±0.4 seconds shorter than for the backs (3.1±1.6 seconds, *p* <0.01). The forwards had 2± 2 sprints (15%) per game that involved a change of direction, which was 4±3 (*p*= 0.03) fewer than for the backs (6±3, 22%). Backs achieved speeds of 90–99% of V˙ max 4±3 times more than did forwards (*p*< 0.01).
Deutsch et al [58]	TMA.	29 elite rugby players <u>Players classified as</u> FRF (n=9 players) BRF (n=7 players) IB= (n=7 players) OB= (n=6 players) Forwards (n=16) Backs (n=13)	<u>Locomotion</u> Standing still Walking Jogging Cruising √ Sprinting√ Utility <u>Non-running intensive exertion</u> Rucking/mauling √ Tackling √ Scrummaging√ <u>Discrete activities</u> Kicking Jumping Passing	Standing still= forwards spent significantly more time than backs (47.7±4.6 vs. 41.1±5.5) Jogging= forwards jogged more (p<0.0125) Walking, utility, cruising, sprinting, cruising= backs spent significantly more time than backs (p<0.0125) Jumping=no significant difference between groups. Rucking/mauling=forwards spent significantly more time than backs (p<0.0125). Tackling=no significant difference between forwards and backs (23.1±14.0 vs. 23.4±10.2; p>0.0125). Scrums= no significant difference between FRF vs. BRF. Work to rest ratios=forwards significantly performed more HI work than backs. The mean rest period=longer for backs than forwards; Rucking/mauling and scrums=contributed 80-90% of forwards HI work. Forwards spent approximately 10minutes/match engaged in static, high contact activities such as tackling, scrummaging, rucking and mauling. Cruising and sprinting=contributed 60-70% of HI work for backs.
Roberts et al [40]	TMA using multiple cameras	29 elite rugby players <u>Players grouped as</u> Forward (n=14) Backs (n=15) <u>Players sub-divided as:</u> Tight forwards (n=8) Loose forwards (n=6) Inside backs (n=7) Outside backs (n=8)	<u>Locomotor data</u> Standing=0-0.5ms^{-1} Jog=1.7-3.6ms^{-1} MI running=3.6-5.0m.s^{-1} HI running√=5.0-6.7m.s^{-1} MS running√= > 6.7m.s^{-1} <u>Static exertion</u> Scrums√ Rucks √	Total distance travelled=backs> forwards (6127±724m vs. 5581±692m) Total distance standing =forwards> backs (354±50m vs. 293±63m) Total distance travelled walking and in high-intensity running=backs> forwards (2351±287m vs. 1928±234m; 448±149m vs. 298±107m respectively) Total time spent walking=backs>forwards (36:47±3:41sec vs. 28:03±3:29sec)

	Mauls √	Total distance travelled jogging and in MI running =No significant difference between backs and forwards
	Line-out lifts	
	Tackles	Sprinting distance=forwards (164±189m) and backs (207±185m).
		No significant difference in total time spent in standing, jogging and MI running between backs and forwards.
		Total time in LI activities=backs> forwards (76:56±1.01sec vs. 70:51±1:39sec).
		Total time spent in HI activities=forwards>backs (9.09±1:39sec vs. 3:04±1:01sec).
		Frequency/Number of HI runs=backs> forwards (59±28 vs. 41±16) ($p<0.05$)
		Average duration of high intensity runs=No significant difference between backs and forwards.
		Number of sprints=Backs> forwards (23±19 vs. 16±15) ($p<0.05$)
		Average duration of sprints=No significant difference between forwards and backs.
		Frequency of static exertions=forwards>backs (89±21 vs. 24±10) ($p<0.05$)
		Average duration of static exertions=forwards> backs (5.2±0.8 vs. 3.6±0.8) ($p<0.05$)

Cunniffe et al [61]	Global Positioning System (GPS) -Tri-axial Accelerometer -Heart rate monitor	2 elite rugby players. <u>Played grouped as:</u> Forward (n=1) Back (n=1)	<u>Locomotor categories</u> Standing and walking=0-6km/hr Jogging=6-12km/hr Cruising=12-14km/hr Striding=14-18km/hr HI running=18-20km/hr Sprinting= >20km/hr <u>Further coding</u> LI activity= 0-8km/hr Moderate-and-HI activity= >8kmr.	The back spent more time at 80-90% HRmax (42%) vs. forward (27.7%). Forward spent more time at 90-95% HRmax (15.4% vs. 4.7%). Mean HR was higher in first half than second half (173 vs. 169b.min^{-1}) 72% game time was spent standing and walking 18.6% jogging, 3.8% striding, 1.0% high-intensity running, and 1.2% sprinting. Work to rest ratio=1:5.7 Players covered=6.953m distance; of this distance=37% was spent standing/walking, 27% jogging, 10% cruising, 14% striding, 5% high-intensity running, and 6% sprinting. Moderate to intense accelerations occurred at intervals of 4 to 6 seconds Backs entered high speed zones frequently than forwards Forward entered lower speed zones frequently than backs Forward spent less time standing and walking than the backs (66.5 vs. 77.8%).

Austin et al [28]	TMA	20 elite rugby players <u>Played grouped as</u> FRF (n=5 players) BRF (n=5 players) IB (n=5 players) OB (n=5 players	<u>Locomotion patterns</u> Standing Forward walking Backward walking Forward jogging Backward jogging Forward striding √ Forward sprinting√ Lateral movement <u>Non-running intense activities</u> Tackling √ Static holds√ Scrummage √ <u>Discrete activity</u> Kicking	Maximum distances: FRF= 5139m; BRF=5422m; IB= 6389m; OB= 5489m Mean (±SD) for total distances (FRF=4662±659m; BRF=5262±131m; IB=6095±213m; OB=4774±1017m) fw, fj=comprised 65% of total distances covered by FRF fw, fj=comprised 63% of total distance covered by BRF fw, fj=comprised 56% of total distance IB fw, fj=comprised 58% of total distance OB. fs, fws=comprised 31% total distance=FRF fs, fws=comprised 32% total distances=BRF fs,fws=comprised 38% total distance=IB fs, fws=comprised 33% total distance=OB Total average sprinting distance (FRF=501±163m; BRF=547±55m; IB=918±253m; OB=558±282m) Average match time (FRF=84±9min; BRF=92±9min; IB=89±1min; OB=72±20min) Average sprinting times (FRF=110±36 sec; BRF=141±8s; IB=203±47s; OB=131±74s) Time spent in HI exercise (FRF=1015±222s; BRF=1190±241s; IB=876±161s OB=570±91s) Work to rest ratio (FRF=1:4; BRF=1:4; IB=1:5; OB=1:6)
Coughlan et al [7]	GPS Gyroscope Digital compass Accelerometer TMA	2 elite rugby players (mean age=30yrs) <u>Players grouped as</u> Forward (n=1) Back (n=1)	<u>Locomotion data</u> Standing=0-0.5m/s Walking=0.5-1.7m/s Jogging=1.7-3.6m/s MI running=3.6-5.0m/s HI running=5.0-6.7m/s MS running=>6.7m/s	Total distance=backs>forwards (7002m-6427m) All players covered greater distance in the 2nd half compared to 1st half Players completed 75% of the total distance in lower intensity activities Standing/walking=forwards> backs High-intensity running/maximal speed=Backs> forwards Forwards sustained higher number of impacts and total body loads Majority of impacts were light.

Hartwig et al [51]	TMA GPS	118 male adolescent rugby players (15.9±0.9 yrs) <u>Players grouped as:</u> Forward Back	<u>Movement patterns</u> Stationary (0-1 $km.h^{-1}$) Walking (1-7$km.h^{-1}$) Jogging (7-12 $km.h^{-1}$) Striding (12-21 $km.h^{-1}$) Sprinting (21+ $km.h^{-1}$)	No significant difference in the percent time spent stationary (38%vs. 45%) and walking (42% vs 45%) during games and training. More time spent in HI movements of jogging, striding and sprinting in matches compared to training. Forward and back players covered greater distance per 1 hr of play in matches (3 795±565m and 4140±460m) compared to training (2 595±680m and 2 920±800m) Players covered 48% more distance/hr during games than training Players performed more sprints per hour, and spent more time sprinting during matches The median distance sprinted during games was 313m greater compared to training The duration and median distances of single sprints were no different btwn games and training Median max sprint was also similar Backs spent less time stationary (33 vs. 45%) and more time walking (49 vs. 36%) than forwards Backs sprinted more frequently and for longer durations than forwards during both games and training
Venter et al [50]	GPS. Accelerometer	17 Under-19 semi-professionals male rugby players (18.5±0.5 years) <u>Players grouped as</u> FRF BRF IB OB	Speed of players grouped as: Standing (0-1 $km.h^{-1}$) Walking (<20% Vmax Jogging (20%-50% Vmax) Striding (51%-80% Vmax) Sprinting (81%-95% Vmax) Maximum sprint (96-100% Vmax.	Time spent walking=Backs spent more (OB) Time spent jogging=forwards spent more time (Props and locks) Time sprinting=Backs spent more time (OB) Mean total distance=4469.95±292.25m FRF= covered the greatest total distance Max. Speeds=no significant difference between positional groups BRF=had the highest total amount of impacts.
Quarrie et al [44]	TMA	763 elite adult rugby players <u>Players grouped as:</u> Tight forwards Loose forwards Inside backs	<u>Speed grouped as :</u> <0.1ms^{-1} 0.1-2ms^{-1} 2-4ms^{-1} 4-6ms^{-1} 6-8ms^{-1}	Distance moved during active time (ball in play) =3 700-4 500m. Props and hookers moved greater distances than flankers at speeds btwn 2.0 and 4.0$ms^{-1.}$ Flankers moved further at 6.0-8.0ms^{-1} Flankers and Number 8 moved greater distance at

		Midfield backs Outside backs	≥8ms^{-1}	speeds > 8.0ms^{-1} Wings moved further as speeds in excess of 8ms^{-1} than scrum-halves and fly-halves Wings and full back travelled further at speeds of < 2.0ms^{-1} than scrum halves or fly-halves. Active time per match=36:21±2:40mins Time between plays=53.34±5:27mins Players from all positions stationary between 9% and 15% of the active time. Forwards approximately stationary 5min per match. This was 90-120s longer per match than backs. 45-53% of active time=spent moving between 0.1 and 2.0ms^{-1} Scrum-halves spent more time/match moving at speeds greater than 4.0ms^{-1} Scrum-halves and fly-halves handle and pass the ball more frequently. Scrum-halves> fly halves. Inside and midfield backs make more tackles/match than outside backs. Wings make more tackles than full backs. Hookers' frequently substituted forwards Open-side flankers the least substituted.
Suarez-Arrones et al [62]	Tri-axial accelerometer HR transmitter GPS unit	9 elite adult male rugby players (25.9±4 years) <u>Players grouped as:</u> Forwards Backs	<u>Movement zones</u> Standing and walking=(0.1-5.9km/hr Jogging=6-11.9 km/h Cruising=12-13.9 km/h Striding=14-17.9km/h High intensity running=18-19.9 km/h Sprinting => 20km/hr.	Mean total distance covered by all players =6162±313 m Backs covered a significant distance than forwards (6471±422 vs. 5853±205m) The average speed in a match=4.30±0.14km.h^{-1}; significantly higher for forwards than backs. Peak speed reached=31.7km.h^{-1} Average number of sprints=backs > forwards (26.2±10 vs. 11±5) Average maximal speed= backs> forwards (28.2±2.5 vs. 24.6±1.5) Average maximal sprint distance= backs>forwards (46.3±12.1 vs. 25.9±8.9) Average sprint distance=backs> forwards (19.5±3.9 vs. 14.7±2.5) Players work-to rest ratio: 1:0.8 No significant difference in mean and peak HRs

				All players received a large number of impacts during the game. Positional differences were observed though. Forwards sustained heavy impact than backs (143.1±122 vs. 29.8±9). Forwards sustained also moderate heavy impact than backs (161.6±107 vs. 54.3±28.9) Grouping of game impacts as (heavy+very heavy+severe) forwards had an impact average of 220 while backs 71.
Cahill et al [18]	GPS	120 elite adult rugby players (27.5±4.2 years) <u>Players grouped as:</u> Forward Backs <u>Further classification</u> FRF Second row BRF Scrum half IB OB	<u>Locomotive variables</u> Standing and walking (<20% Vmax) Jogging (20-50% Vmax) Striding (51-80% Vmax) Sprinting (81-95% Vmax) Maximum sprint (96-100% Vmax).	Total distance= backs >forwards (median ±IQR, 6545±1055 vs 5850±1101); % difference was 11.9. Standing/walking=backs> forwards Jogging=forwards covered most of their distance jogging than backs. Backs covered greater distances , moved at higher speeds than forwards Backs covered more distance sprinting than forwards Forward spent more time striding Scrum half covered the greatest absolute distances.
Lacome et al [63]	TMA Velocity corresponding to BL concentration	30 elite adult rugby players (Age range=22-33years) <u>Players grouped as</u> Forwards (n=17) Backs (n=13) FRF (n=9) BRF (n=8) IB (n=6) OB (n=7)	<u>Acceleration values</u> Standing-walking=0-7km/hr Jogging=7km/hr MI run Higher than maximal aerobic velocity. <u>Static exertions</u> Scrums Rucks Maul.	Body mass greater in forwards than in backs All players had similar heights Front row forwards heaviest, outside backs lightest No significant difference relative to body fat, VLa4 (velocity corresponding to a blood lactate concentration of 4mmol.l^{-1}), maximal aerobic velocity or age. VLa4 related to the maximal aerobic velocity (VLa4%) was significantly lower in backrows than in outside backs. FRF, BRF=show similar mean total exercise times IB had 10±1.4min on the mean total exercise time similar to back rows and shorter than front rows and longer than OBs. Backs covered more distance than forwards (7 994±659m vs. 7 006±356m).

				FRF=covered the shortest distance IB and OB= covered similar distances Total number of E:R ratios= forwards> backs Forwards more involved in static activity than backs Backs more involved in supra maximal intensity bouts Mean acceleration duration significantly higher in backs than in forwards Mean acceleration values significantly higher in forwards than backs.
Reid et al [45]	GPS Gyroscope digital compass	8 elite male adult rugby union players (Age: 27.86 ± 4.78 years) <u>Players grouped as:</u> Forwards Backs <u>Players sub-grouped as:</u> <u>Forwards</u> Loose head prop Lock Open side flanker Scrum half <u>Backs</u> Fly half Inside centre Wing Fullback	<u>Locomotor data</u> Standing=0-0.5m/s Walking=0.6-1.7m/s LI running=1.8-3.6m/s MI running=3.7-5.0m/s HI running=5.1-6.7m/s MS running=≥6.8m/s	Total distance=ranged from 6 206.2m to 7183.7m Backs covered greater total distance. Scrum half completed the most (7183.7m). Loose head prop the least. Highest peak speed=wingers (31.1kn/hr) Lowest peak speed=Lock Flankers=fastest forwards (28.4km/hr) Standing/walking=No significant difference between forwards for time spent and distance spent. Backs spent less time and covered less distance in walking than forwards. LI running zone=Loose-head prop and locks spent longer durations and covered more distance than other forwards. High speed running zones=flankers spent longer durations and covered more distance. Maximal speed running=scrum halves and locks did not enter in this maximal running zone.
Portillo et al [48]	GPS HR monitor	22 elite male under-19 rugby union players (age= 18.6 ± 0.5 years) <u>Players grouped as:</u> Forwards (n=13) Backs (n=9)	<u>Movement categories</u> Standing/walking (0-6km/hr) Jogging (6-12km/hr) Cruising (12-14km/hr) Striding (14-18km/hr) HI running (18-20km/hr) Very-HI running (>20km/hr) <u>Further grouping</u> LI=0-8km/hr Moderate and HI	No significant difference in total time played btwn forwards and backs =(65.1±14.9min vs. 58.0±14.1min) Total distance covered= (forwards=78.4±4.5m/min vs. back=83.0±10.0m/min; p=0.225) No significant difference on average speed, maximal heart rate, and average heart rates between backs and forward. Backs covered 19.2% greater distance than forwards at the 0-6km/hr At jogging and cruising=forwards covered 25.2% and

			activity=>8.0km/hr.	26.2% greater distance respectively than backs. Backs also covered greater distance at 20km/hr than forwards. No significant difference between backs and forwards in total distance (5892.4±469.9 forwards vs 5997.6±1007.9m backs). Backs covered a greater number of intensity runs than forwards Backs had a greater number of maximum speed runs and covered greater mean distance per very high intensity run than forwards.
Reardon et al [39]	GPS	36 elite professional rugby players <u>Players grouped as:</u> Forward Back <u>Positional sub-group:</u> Prop Hooker Second row Number 8 Flanker Out-half Scrum half Centre Wing Full back	<u>Locomotor variables</u> Total distance Total distance relative to playing time Maximum velocity HSR (High speed running)	Total distance=back> forward ($p< 0.001$) Relative distance: Backs > forwards (71.61±10.14 vs 81.02±10.2) In-game maximum velocity= Backs> forwards (7.94 ±0.64 vs. 6.89±0.61) High speed running distance= Backs> forwards (564.68±141.32 vs. 359.09±140.38) HSR%=% of total distance at HSR=Backs> forwards (9.28±2.50 vs. 6.79±2.56) High speed running efforts per minute=Backs> forwards (34.07±8.99 vs. 25.16±8.91) High speed running distance per minute= backs> forwards= (7.41±1.76 vs. 4.77±1.74).
Tee et al [60]	GPS Inbuilt triaxial accelerometer	19 professional rugby from South Africa (Mean age±SD= 26±2years) <u>Players grouped as:</u> Tight forwards Loose forwards Scrum halves Inside backs Outside backs	<u>Movement patterns</u> Walking (0-2ms^{-1}) Jogging (2-4ms^{-1}) Striding (4-6ms^{-1})√ Sprinting (> 6ms^{-1})√	No significant difference in relative distance covered in match play btwn backs and forwards Scrum halves covered greater distance than all other positional groups Backs had greater maximum speed compared to forwards Forwards covered more distance walking and jogging Backs covered twice as much while sprinting Striding=no significant difference between backs and forwards Forwards covered more distance in low-intensity

				ranges Backs covered more distance in high-intensity ranges High: low intensity ratio= 1.8 for forwards, 1:4 for backs 79-84% of playing time was spent walking for all positions Walking=Backs spent more time Jogging=Forwards spent more time Striding=No significant difference between backs and forwards Backs performed maximal accelerations 1.5 times more often than forwards Impact=no difference in the total number of impacts btwn backs and forwards.
Jones et al [55]	GPS unit sampling at 10Hz Tri-axial piezoelectric linear accelerometer system sampling at 100Hz.	33 professional rugby players <u>Players grouped as:</u> Tight forwards Loose forwards Half backs Inside backs Outside backs	<u>Movement patterns</u> Walking (0-1.6ms^{-1}) Jogging (1.6-2.7ms^{-1}) Cruising (2.7-3.8ms^{-1}) Striding (3.8-5.0ms^{-1}) High intensity running (5.0-5.5ms^{-1})√ Sprinting (>5.6ms^{-1})√	IB and OB had the greatest high speed running demands; RHIE (repeated high intensity exercise) and contact demands greatest in loose forwards during match play.
Vaz et al [54]	GPS unit Accelerometer HR monitoring	28 young rugby players. <u>Players grouped as:</u> Under 16=cluster 1(15.4±1.1 years) Under 18=cluster 2 (16.6±0.8 years)	<u>Locomotion variable</u> Zone 1= 0-6.9km/hr Zone 2=7.0-9.9 km/hr Zone 3=10.0-12.9km/hr Zone 4=13-15.9km/hr Zone 5=16-17.9 km/hr Zone 6=≥18.0 km/hr	Cluster 1 players showed higher values in all speed zones for the distance covered. Total body impacts were found higher in Cluster 1 players than in Cluster 2.
Cunningham et al [52]	GPS	40 elite junior players <u>Players grouped as:</u> Front row Second row (SR) Back row Half backs (HB) Midfield (MB) Back three (B3)	<u>Locomotor variables</u> Total distance Distance relative to playing time High speed running (HSR) HSR relative to playing time Number of sprints Number of sprints relative to playing time Moderate, high, and sever intensity accelerations and decelerations High metabolic load distance	Total distance=backs> forwards (6. 23km±0.80 vs. 5.37km±0.83). Mean and standard deviations for all locomotor variables included were greater for the backs, with the exception of number of accelerations 3-4ms^{-1} U20 backs covered more distance per minute than forwards The number of sprints performed by backs were double than that of forwards. Forwards are involved in higher number of collisions

			High metabolic load efforts	than backs Backs cover greater HSR distances
Cunningham et al [88]	GPS	40 elite professional junior players <u>Players grouped as:</u> Front row Second row (SR) Back row Half backs (HB) Midfield (MB) Back three	<u>Locomotor variables</u> Total distance relative to playing time High speed running HSR relative to playing time Number of sprints relative to playing time High metabolic load efforts (HML)	Forwards=seniors covered greater HML distance (736.4±280.3 vs. 701.3±198.7m), and severe decelerations (2.38±2.2 vs. 2.28±1.65) compared to U20. But seniors performed less relative HSR (3.1 ±1.6 vs. 3.2±1.5), moderate (19.4±10.5 vs. 23.6±10.5) and high accelerations (2.2±1.9 vs. 4.3±2.7) and sprint time (0.11±0.06 vs. 0.11±0.05). Senior backs covered a greater relative distance (73.3±8.1 vs. 69.1±7.6m/min), greater high metabolic load (HML) distance (1138±233.5 vs. 1060.4±218.1m), HML efforts (112.7±22.2 vs. 98.8±21.7) and heavy decelerations (9.9±4.3 vs. 9.5±4.4) than the U20 backs.
Tee et al [56]	GPS	53 male rugby players <u>Players grouped as:</u> Tight forwards Loose forwards Scrumhalf Inside backs Outside halves	<u>Movement data</u> Walking (0-2ms^{-1}) Jogging (2-4ms^{-1}) Striding (4-6ms^{-1})√ Sprinting (> 6ms^{-1})√	Total distance covered in match=5050±1636 Total distance covered in training=4479±1804-5787±1212. Maximal speed= no significant difference in maximal speed between matches and training Players walked more in matches vs. training (34.5±5 vs 25±6)
Read et al [38]	GPS Accelerometer	112 rugby players <u>Players grouped as</u>: Forwards Backs <u>Players sub-divided as:</u> U-16 U-18 U-20	<u>Velocity zones</u> Low-speed running= (0-3.33m.s^{-1}) High speed running=(>3.33m.s^{-1})	Relative distances and HSR/min were greater for backs PL/min and PL_{slow}/min were greater for forwards PL/min was higher in U-18

Front row forwards=FRF; Backrow forwards=BRF; Inside backs=IB; Outside backs=OB. SR= second row; √ signifies activities classified as “work” or high-intensity activities in the respective studies; fw=forward walking, fj=forward jogging; fs=forward striding, fws=forward sprinting; SD= standard deviation; U= under, HI=high-intensity, LI=low-intensity, MI=Medium intensity; MS= Maximum speed; GPS=Global positioning system; TMA=Time motion analysis; BL=Blood lactate concentration; HR=Heart rate; Vmax=Maximum velocity; PL=Player load; Player load slow=PLslow; HSR=high speed running

Appendix B: Qualities or skills discriminating players of intermittent team contact sports

Authors	Group comparisons	Test battery	Anthropometrics results	Physiological results	Game-skills results
Durandt et al [72]	Group 1: U16 years (n=92) Group 2: U18 years (n=82)	**Anthropometrics**: height, mass, sum of 7 skinfolds **Physical**: bench press absolute, bench press relative, pull ups, push ups, 10m speed, 40m speed, illinois agility, multistage shuttle run	Group 1 *vs.* Group 2 Height: 175.6 ±5.7cm *vs.* 179.2± 6.7cm (p<0.001) Mass: 76.5± 8.2 kg *vs.* 84.9 ±8.3kg (P<0.0001) Sum of 7 skinfolds: 66.8± 19.2 *vs.* 69.2 ±20.6 (p=0.51) % body fat: 14.5± 3.4 *vs.* 14.3± 2.7 (p=0.70)	Group 1 *vs.* Group 2 Bench press absolute: 77.1 ±11.8kg *vs.* 95.3± 16.7kg (p<0.01) Bench press relative: 6.55 ±1.00 *vs.* 7.54 ±1.30 (p<0.01) Pull Ups: 10± 5*vs.* 11± 6 (P=0.1) Push Ups 41±12 *vs.* 52± 15 (p<0.01) 10m speed: 1.9 ±0.1 *vs.* 1.9 ±0.1 (p=0.70) 40m speed: 5.5± 0.2 *vs.* 5.5± 0.1 (p=0.15) Illinois agility test 15.2±0.9 *vs.* 15.1±0.8 (p=0.42) Multistage shuttle run test 87.1 ±19.4 *vs.* 93.5± 15.3 (p<0.05)	not assessed

Gabbett et al [74]	Group 1: First grade players (n=26) Mean age=23.7 ±4.3 years Group 2: Second grade players (n=40) Mean age= 24.4±5.0 years Group 3: Third grade players (n=20) Mean age=17.8±1.5 years	**Anthropometrics**: height, skinfold thickness **Physical**: 10m sprint, 20m sprint, 40m sprint, agility, vertical jump, VO_{2max} **Game-skills:** General skills, evasion skills, tackling and defensive skills, offensive skills	Group 1 *vs.* Group 2 Mass: 92.2± 11.4kg *vs.* 88.9± 9.0kg Height: 179.0± 7.3cm *vs.* 180.1± 5.2cm Skinfold thickness: 44.0 ±10.1 *vs.* 40.3 ±11.8 Group 1 vs. Group 3 Mass: 92.2 ±11.4kg *vs.* 81.5± 20.2kg Height: 179.0 ±7.3 *vs.* 177.6 ±7.9cm Skinfold thickness: 44.0 ±10.1mm *vs.* 37.4 ±15.9mm Group 2 vs. Group 3 Mass: 88.9 ±9.0kg *vs.* 81.5 ±20.2kg Height: 180.1± 5.2 *vs.* 177.6 ±7.9 cm Skinfold thickness: 40.3± 11.8mm *vs.* 37.4± 15.9 mm	Group 1 *vs.* Group 2 10m sprint: 2.06± 0.18 vs. 2.12± 0.19 20m sprint: 3.36 ±0.23 *vs.* 3.44 ±0.22 40m sprint: 5.90± 0.19 vs. 5.92± 0.35 Agility: 5.90± 0.19 *vs.* 6.25± 0.52 Vertical jump: 50.7± 9.8 *vs.* 45.2 ±8.4 VO_2max: 46.9 ±5.8 *vs.* 45.6 ±5.7 Group 1 *vs* Group 3 10m sprint: 2.06 ±0.18 *vs.* 2.09± 0.26 20m sprint: 3.36± 0.23 *vs.* 3.44± 0.27 40m sprint: 5.90± 0.19 *vs.* 5.96 ±0.38 Agility: 5.90± 0.19 *vs.* 6.25 ±0.48 Vertical jump: 50.7 ±9.8 *vs.* 44.3± 11.9 VO_2max: 46.9 ±5.8 *vs.* 47.6± 7.6 Group 2 *vs.* Group 3 10m sprint: 2.12± 0.19 *vs.* 2.09± 0.26 20m sprint: 3.44 ±0.22 *vs.* 3.44 ±0.27 40m sprint: 5.92± 0.35 *vs.* 5.96 ±0.38 Agility: 6.25± 0.52 *vs.* 6.25 ±0.48 Vertical jump: 45.2 ±8.4 *vs.* 44.3 ±11.9 VO_2max: 45.6± 5.7 *vs.* 47.6± 7.6	Group 1 vs. Group 2 General skills Catching: 3.6 ±0.9 vs. 3.3±0.8 Ball carrying: 4.0±0.7 vs. 3.4±0.8 Basic passing: 3.7± 0.9 vs. 3.2± 0.8 Skills under fatigue: 3.9 ±0.8 vs. 3.4 ±0.7 Evasion skills Beating a player: 3.8± 0.8 *vs.* 3.1± 0.9 2 verse 1: 3.9± 0.9 vs. 3.5± 0.9 Tackling and defensive skills Side on tackle: 3.5± 0.7 vs. 3.5±0.8 Head on tackle: 3.6 ±0.8 vs. 3.5 ±0.8 Rear tackle: 3.6 ±0.7 vs. 3.4± 0.7 Defensive shape, speed and space: 3.5± 0.7 vs. 3.4± 0.7 Offensive skills Hit and spin: 3.5 ±0.8 vs. 3.6 ±0.9 Play the ball: 4.0 ±0.8 vs. 3.7± 0.9 Pass out of tackle: 3.6± 0.7 vs. 3.5± 0.8 Grade 1 vs. Grade 3 General skills

					Catching: 3.6 ±0.9 vs. 3.3±0.6 Ball carrying: 4.0±0.7 vs. 3.4±0.7 Basic passing: 3.7± 0.9 vs. 3.2± 0.8 Skills under fatigue: 3.9 ±0.8 vs. 3.5±0.9 <u>Evasion skills</u> Beating a player: 3.8± 0.8 *vs.* 3.1± 0.7 2 verse 1: 3.9± 0.9 vs. 3.4± 0.9 <u>Tackling and defensive skills</u> Side on tackle: 3.5± 0.7 vs. 3.2±0.7 Head on tackle: 3.6 ±0.8 vs. 3.4 ±0.7 Rear tackle: 3.6 ±0.7 vs. 3.4± 0.8 Defensive shape, speed and space: 3.5± 0.7 vs. 3.1± 0.7 <u>Offensive skills</u> Hit and spin: 3.5 ±0.8 vs. 3.3 ±0.7. Play the ball: 4.0 ±0.8 vs. 3.8± 1.0 Pass out of tackle: 3.6± 0.7 vs. 3.2± 0.7 <u>Grade 2 vs. Grade 3</u> <u>General skills</u> Catching: 3.3 ±0.8 vs. 3.3±0.6

					Ball carrying: 3.4±0.8 vs. 3.4±0.7 Basic passing: 3.2± 0.8 vs. 3.2± 0.8 Skills under fatigue: 3.4 ±0.7 vs. 3.5±0.9 <u>Evasion skills</u> Beating a player: 3.1± 0.9 *vs*. 3.1± 0.7 2 verse 1: 3.5± 0.9 vs. 3.4± 0.9 <u>Tackling and defensive skills</u> Side on tackle: 3.5± 0.8 vs. 3.2±0.7 Head on tackle: 3.5±0.8 vs. 3.4 ±0.7 Rear tackle: 3.4 ±0.7 vs. 3.4± 0.8 Defensive shape, speed and space: 3.4± 0.7 vs. 3.1± 0.7 <u>Offensive skills</u> Hit and spin: 3.6 ±0.9 vs. 3.3 ±0.7. Play the ball: 3.7 ±0.9 vs. 3.8± 1.0 Pass out of tackle: 3.5± 0.8 vs. 3.2± 0.7

Gabbett et al [75]	Group 1: First grade players (n=12) Group 2: Second grade players (n=30) Mean age of all participants (23.6±5.3years)	**Physical**: 5m speed test, 10m speed test, 20m speed test, 505 test, modified 505 test, Lrun test **Game-skills:** Reactive agility	Not assessed.	<u>Group 1 *vs.* Group 2</u> 5m speed test: 1.14 ±0.06 vs. 1.20± 0.11 (ES=0.68, Moderate) 10m speed test: 1.90± 0.09 *vs.* 2.00± 0.14 (ES=0.85, Large) 20m speed test: 3.25± 0.16 *vs.* 3.39± 0.21 (ES=0.75; Moderate) 505 test: 2.34 ±0.20 *vs.* 2.39± 0.15 (ES=0.28; Small) Modified 505 test: 2.66± 0.14 *vs.* 2.71± 0.17 (ES=0.32; Small) L-run test: 6.36 ±0.53 *vs.* 6.49± 0.40 (ES=0.28, Small)	<u>Group 1 *vs.* Group 2</u> Reactive agility Movement time (s): 2.48±0.17 vs. 2.60±0.16 (ES=0.73, Moderate) Decision time (ms): 55.3±43.6 vs. 78.2±40.4 (ES=0.54, Moderate) Response accuracy (%): 89.3±13.9 vs. 84.0±17.3 (ES=0.34, Small)
Baker [76]	Group 1: NRL (n=19) Group 2: SRL (n=19)	**Physical:** repetitions-to-fatigue test bench pressing a relative resistance equal to 60% of 1RM BP (RTF BP 60% 1RM).	Not assessed	<u>Group 1 vs. Group 2</u> RTF BP 60: 36.1± 7.2 *vs.* 28.0± 5.6 RTF BP 102.5: 12.5± 4.3 *vs.* 5.9± 3.9	Not assessed

Spamer et al [77]	Group 1: (n=24) New Zealand U16 rugby players Group 2: (n=43) U16 schoolboy rugby players in NWP Group 3: (n=21) U16 rugby players in the NWP competing at national tournament	**Anthropometrics:** 7 skinfolds, mass, height, girth measurements **Physical:** sit-and-reach, vertical jump, speed endurance, zig-zag run, speed 10m and 45.7m, flexed arm hang **Game-skills:** ground skills, side steps, air and ground kicks, passing distance, passing accuracy over 4m/7m, kicking distance, and kick-off distance	Group 1*vs* Group 2 Medium to large effect size for: Mass 81.26±8.31*vs*. 72.82±9.63 (ES=0.9) Supra-spinal 20.69±9.29 *vs*. 11.91±5.54 (ES=0.9) Pectoral 9.73±3.44 *vs*. 6.80±2.75 (ES=0.9) % fat=13.66±4.77 *vs*. 18.77±6.44 (ES=0.8) FUA 33.73±2.88 *vs*. 32.05±2.33 (ES=0.6) Forearm 28.41±1.58 *vs*. 27.45±1.66 (ES=0.6) Ankle 24.80±1.22 *vs*. 23.89±1.71 (ES=0.5) Abdomen 20.73±9.89 *vs*. 15.60±8.92 Mid-axilla 13.25±7.57 *vs*. 9.63±4.49 Sub-scapular 14.46±7.06 *vs*. 10.99±4.4`1 (ES=0.5) Group 1 vs. Group 3 Medium to large effect size for: Triceps 12.96±4.48 *vs*. 8.02±2.81 (ES=1.1)	Group 1 *vs* Group 2: Medium to large effect size for: Zig zag run 6.65±0.44 vs. 7.16±0.48 (ES=1.1) Speed 45.7m 6.21±0.38 vs. 6.61±0.34 (ES=1.1) Group 1 vs. Group 3: Medium to large effect size for Sit and reach -2.21±8.75 *vs*. 5.91±6.80 (ES=0.9) Vertical jump 50.07±7.00 *vs*. 40.55±10..67 (ES=0.9) Speed 10m 1.79±0.09 *vs*. 1.89±0.20 (ES=0.5) Flexed arm hang 38.63±16.17 *vs*. 26.03±12.04 (ES=0.8).	Group 1 vs. Group 2 Ground skills: 3.27± 0.22 vs. 5.68 ±0.36 (ES=6.7, Medium effect) Side steps: 5.96 ±2.46 vs. 4.46 ±1.35 (ES=0.6, Medium effect) Air and ground kicks: 7.13 ±1.92 vs. 4.60 ±1.90 (ES=1.3, Large effect) Passing distance: 21.96 ±2.71 vs. 19.95± 3.27 (ES=0.6, Medium effect) Passing accuracy 4m: 3.83 ±1.88 vs. 4.23± 2.36 (ES=0.1, Small) Passing accuracy 7m: 24.42± 3.12 vs. 25.69± 2.57 (ES=0.4, Small) Kicking distance: 40.9± 4.60 vs. 38.02± 6.56 (ES=0.4, Small) Kick-off distance: 37.59± 4.37 vs. 36.07± 7.80 (ES=0.2, Small). Group 1 vs. Group 3 Ground skills: 3.27± 0.22 vs. 3.62 ±0.25 (ES=1.4, Large effect) Side steps: 5.96 ±2.46 vs. 5.50 ±1.40 (ES=0.2, Small effect) Air and ground kicks: 7.13 ±1.92 vs. 5.19 ±0.93 (ES=1.0, Large

			Subs-scapular 14.49±7.06 *vs*. 10.32±2.77 (ES=0.6) Pectoral 9.73±3.44 *vs*. 5.73±2.30 (ES=1.2) Thigh 17.15±5.22 *vs*. 10.77±4.01 (ES=1.2) Abd 20.73±9.89 *vs*. 12.64±6.52 (ES=0.8) Calf 11.75±4.64 *vs*. 7.11±2.84 (ES=1.0) % body fat 13.66±4.77 *vs*. 15.96±3.96 (ES=0.5)		effect) Passing distance: 21.96 ±2.71 vs. 21.14± 4.34 (ES=0.2, Small effect) Passing accuracy 4m: 3.83 ±1.88 vs. 4.50± 2.28 (ES=0.3, Small) Passing accuracy 7m: 24.42± 3.12 vs. 23.55± 5.76 (ES=0.2, Small) Kicking distance: 40.9± 4.60 vs. 41.41± 11.3 (ES=0.04, Small) Kick-off distance: 37.59± 4.37 vs. 33.60± 9.18 (ES=0.4, Small).
Spamer and De la port [73]	Group 1: U16 year olds 2003 (n=71), 2004 (n=69) Group 2: U18 year olds 2003 (n=75), 2004 (n=71)	**Anthropometry**: height, mass, sum of 7 skinfolds, muscle %, body fat%, endomorphy, mesomorphy, ectomorphy **Physical and motor abilities:** 10m run, 40m run, illinois agility test, speed endurance, bench press, pull-ups, push-ups **Game skills:** Catching ability, ground skills, passing for accuracy, passing for distance, kicking for distance	<u>Group 1 vs Group 2 2003 results</u> Height: 175.41±8.09 vs. 180.27 Mass: 76.17±11.74 vs. 85.07±12.45 Sum of 7 skinfolds: 67.61±28.29 vs. 76.87±28.31 Muscle %: 63.53±5.29 vs. 62.04±7.41 Body fat%: 14.33±3.94 vs. 15.14±3.40 Endomorphy: 2.91±1.28 vs. 3.23±1.14 Mesomorphy: 5.48±1.17 vs. 5.82±1.89 Ectomorphy: 2.11±1.01 vs. 1.86±1.06	<u>Group 1 vs. Group 2 2003 results</u> 10m run: 1.90 ±0.09 vs. 1.87± 0.11 40m run: 5.54 ±0.21 vs. 5.43± 0.33 Illinois: 15.07 ±0.96 vs. 14.97 ±0.72 Speed endurance: 81.41± 19.09 vs. 96.00 ±17.37 Bench press: 75.52 ±1.50 vs. 95.24± 18.58 Pull ups: 9.46± 1.08 vs. 10.40± 5.45 Push ups: 38.84± 11.18 vs. 50.74 ±27.28	<u>Group 1vs. Group 2 2003 results</u> Catching ability: 12.82± 2.94 vs. 13.94± 3.27 Ground skills: 3.12± 0.18 vs. 3.13± 0.20 Passing for accuracy left 4m: 2.37 ±1.20 vs. 2.81 ±1.16 Passing for accuracy right 4m: 2.29 ±1.22 vs. 2.68 ±1.37 Passing for distance 25.39 ±2.56 vs. 24.39± 2.69 Kicking for distance 42.85± 7.08 vs. 42.77 ±16.00

			Group 1 *vs*. Group 2 2004 results Height: 178.17±7.57 vs. 180.43 Mass: 79.50±13.63 vs. 86.83±13.86 Sum of 7 skinfolds: 73.51±39.07 vs. 70.76±36.80 Muscle %: 61.34±6.34 vs. 61.80±3.53 Body fat%: 15.04±4.18 vs. 14.65±4.06 Endomorphy: 3.15±1.52 vs. 3.10±1.50 Mesomorphy: 5.47±1.24 vs. 5.52±1.90 Ectomorphy: 2.21±1.08 vs. 1.66±1.11	Group 1 *vs*. Group 2 2004 results 10m run: 1.84 ±0.07 vs. 1.85± 0.08 40m run: 5.42±0.22 vs. 5.45± 0.28 Illinois: 15.43 ±1.09 vs. 15.36 ±0.95 Speed endurance: 91.00± 17.00 vs. 93.07 ±16.79 Bench press: 82.89 ±15.87 vs. 105.94± 21.38 Pull ups: 11.33± 4.72 vs. 12.41± 5.32. Push ups: 48.20± 12.87 vs. 58.19 ±14.12	Group 1 *vs*. Group 2 2014 results Catching ability: 15.22± 3.55 vs. 13.8± 3.11 Ground skills:3.18± 0.20 vs. 3.18± 0.21 Passing for accuracy left 4m: 2.61± 1.33 vs. 2.21± 1.33 Passing for accuracy right 4m: 2.51± 1.25 vs. 2.46 ±1.20 Passing for distance 27.95 ±3.74 vs. 26.23± 2.37 Kicking for distance 45.13± 6.33 vs. 44.71± 4.66
Gabbett et al [78]	Group 1: (n=28) Elite junior players (Mean age= 16.0 ±0.2 years) Group 2: (n=13) Sub-elite junior players (Mean age=15.9±0.6 years)	**Anthropometry:** Height, mass, skinfold thickness. **Physiologica**l: 10m speed, 10m velocity, 10m acceleration, and change of direction speed, 505 test, and vertical jump Game skills: Tackling proficiency	Group 1 *vs* Group 2 Height 178.0±5.9 *vs*. 175.2±6.9 (ES=0.45, small) Body mass 77.5±10.0 *vs*. 72.3±11.7 (ES=0.50, moderate) Skinfold thickness 67.1±14.8 *vs*. 76.4±28.1 (ES=0.47, small)	Group 1 *vs* Group 2 10m sprint: 1.81±0.08 vs. 1.94 vs. 0.13 (ES=1.30, large) 10m velocity: 5.54±0.24 vs. 5.19±0.34 (ES=1.28, large) 10m acceleration: 3.08±0.27 vs. 2.70±0.35 (ES=1.22, large) 505 test: 2.30±0.13 vs.	Group 1 *vs*. Group 2 Tackling proficiency: 65.7 ±12.5 vs. 54.3± 16.8 (ES=0.82, Large)

				2.37±0.13 (ES=0.56, moderate) Vertical jump: 51.6±7.7 vs. 46.7±7.0 (ES=0.65, moderate)	
Argus et al [43]	Group 1: Professional (n=43) Mean age=24.4 ±2.7yrs Group 2: Semi-professional (n=19) Mean age 20.9± 2.9 yrs Group 3: Academy (n=32) Mean age 19.6 ±1.8 yrs Group 4: High school (n=18) Mean age 16.6± 0.8 yrs	**Anthropometry:** height, mass **Physiological:** bench press, bench throw, box squat, jump squat	Group 1*vs* Group 2 Height 184.7 ±6.2 vs. 187.2 ±7.6 Mass 103± 11.2 vs. 100.7±11.5 Group 1 *vs.* Group 3 Height 184.7± 6.2vs. 186.9 ±6.5 Mass 103± 11.2 vs. 95.6± 11.0 Group 1 *vs.* Group 4 Height 184.7 ±6.2 vs. 180.9± 8.4 Mass 103.4 ±11.2 vs. 86.5± 13.7 Group 2 *vs.* Group 3 Height 187.2± 7.6 vs. 186.9 ±6.5 Mass 100.7 ±11.5 vs. 95.6 ±11.0 Gr2 vs. Gr 4 Height 187.2± 7.6 vs. 180.9 ±8.4 Mass 100.7 ±11.5 vs. 86.5 ±13.7 Gr3 vs. Gr 4 Height 186.9± 6.5 vs. 180.9± 8.4 Mass 95.6 ±11.0 vs. 86.5 ±13.7	Group 1 *vs* Group 2 Bench press 141 ±21 vs. 134 ±13 Bench throw 1 140 ±220 vs. 880 ±90 Box squat 184± 32 vs. 182± 28 Jump squat 5240 ±670 vs. 4880 ±660 Group 1 *vs* Group 3 Bench press 141± 21 vs. 115 ±13 Bench throw 1140 ±220 vs. 800 ±110 Box squat 184 ±32 vs. 182 ±28 Jump squat 5240 ±670 4430± 950 Group 1 vs Group 4 Bench press 141± 21 vs. 85 ±13 Bench throw 1140± 220 vs. 560 ±140 Box squat 184 ±32 vs. 100 ±19 Jump squat not assessed in Gr4 subjects Group 2 vs Group 3 Bench press 134 ±13 vs. 115 ±16 Bench throw 880± 90 vs.	Not assessed

				800± 110 Box squat 182± 28 vs. 151± 30 Jump squat 4880± 660 vs. 4430 ±950 <u>Group 2 vs Group 4</u> Bench press 134 ±13 vs. 85± 13 Bench throw 880 ±90 vs. 560± 140 Box squat 182± 28 vs. 100± 19 Jump squat not assessed in Group 4 subjects <u>Group 3 vs Group 4</u> Bench press 115± 16 vs. 85± 13 Bench throw 800 ±110 vs. 560± 140 Box squat 151 ±30 vs. 100± 19 Jump squat not assessed in Group 4 subjects	
Gabbett [83]	U14 Group 1 starters Group 2 non starters U16 Group 1 starters Group 2 non starters U18 Group 1 starters Group 2 non starters	**Anthropometry:** height, body mass, sum of skinfolds **Physiological**: 10m sprint, 20m sprint, 40m sprint, change of direction 505, vertical jump, and maximal aerobic power	<u>U14 Group 1 vs. Group 2</u> Height 164.0± 10.9 vs. 159.7 ±9.1 (ES=0.43) Mass 56.8± 15.3 vs. 52.1 ±14.8 (ES=0.31) Sum of skinfolds 34.2 ±18.3 vs. 34.1± 14.1 (ES=0.01) <u>U16 Group 1vs. Group 2</u> Height 172.7 ±4.9 vs. 169.9 ±8.7 (ES=0.40)	<u>U14 Group 1 vs. Group 2</u> 10m speed 2.10 ±0.14 vs. 2.18 ±0.21 (ES=0.45) 20m speed 3.58± 0.25 3.67 ±0.22 (ES=0.38) 40m speed 6.49 ±0.51 vs. 6.68± 0.43 (ES=0.40) CODS 505 test 2.63 ±0.21 vs. 2.70± 0.18 (ES=0.36)	

			Mass 65.2± 9.6 vs. 69.8± 26.3 (ES=0.23) Sum of skinfolds 27.2 ±7.5 vs. 37.0± 25.7 (ES=0.52) <u>U18 Group 1 vs. Group 2</u> Height 178.0± 4.8 vs. 177.5± 7.8 (ES=0.08) Mass 75.6± 14.4 vs. 81.4 ±13.3 (ES=0.42) Sum of skinfolds 35.1± 17.5 41.8 ±21.7 (ES=0.34)	Vertical jump 37.9 ±6.6 37.0 ±6.0 (ES=0.00) Maximal aerobic power 1398 ±392 vs. 1123± 402 (ES=0.69) <u>U16 Group 1 vs. Group 2</u> 10m speed 1.91± 0.05 vs. 2.05± 0.17 (ES=1.12) 20m speed 3.22 ±0.08 vs. 3.52± 0.31 (ES=1.33) 40m speed 5.72± 0.21 vs. 6.34 ±0.68 (ES=1.23) CODS 505 test 2.37 ±0.16 vs. 2.53± 0.33 (ES=0.62) Vertical jump 46.7 ±5.8 vs. 42.4 ±7.2 (ES=0.66) Maximal aerobic power 1411 ±367 vs. 1220± 565 (ES=0.40) <u>U18 Grade 1 vs. Grade 2</u> 10m speed 1.92± 0.06 vs. 1.96± 0.12 (ES=0.42) 20m speed 3.22± 0.09 vs. 3.31 ±0.24 (ES=0.50) 40m speed 5.69 ±0.21 vs. 5.90 ±0.52 (ES=0.53) CODS 505 test 2.32±	

				0.19 vs. 2.43± 0.16 (ES=0.63) Vertical jump 47.8 ±6.7 vs. 46.7 ±9.4 (ES=0.13) Maximal aerobic power 1466 ±259 vs. 1503± 457 (ES=0.10)	
Waldron et al [84]	Group 1: U15 (15.1 ±0.3 years) Group 2: U16 (16.2±0.3 years) Group 3: U17 (17.0±0.3 years)	**Anthropometrics:** seated stature, body mass, maturity offset, sum of 6 skinfolds **Physical:** 20m sprint time, CMJ, predicted vertical power, VO_{2max}	<u>Grade 1 vs. Grade 2</u> Seated stature 93.4± 2.3 vs. 94.6± 1.9 Body mass 81.9± 9.1 vs. 86.1± 6.0 Maturity offset 1.04 ±0.40 vs. 1.73± 0.27 Sum of 6 skinfolds 83.9± 30.3 vs. 81.0 ±25.0 <u>Group 1 vs. Group 3</u> Seated stature 93.4 ±2.3 vs. 94.7 ±2.1 Body mass 81.9± 9.1 vs. 86.3± 9.4 Maturity offset 1.04± 0.4 vs. 2.16 ±0.31 Sum of skinfolds 83.9±30.3 vs. 77.8±20.8 <u>Group 2 vs. Group 3</u> Seated stature 94.6 ±1.9 vs. 94.7± 2.1	<u>Grade 1 vs. Grade 2</u> 20m sprint 3.5 ± 0.1 vs. 3.4± 0.2 CMJ: 47.0± 3.0 vs. 47.3± 4.9 Predicted vertical power: 3 611.3± 327.3 vs. 4 081.5 ± 454.9 VO_{2max}: 48.1± 3.4 vs. 48.3± 3.6 <u>Gr1 vs. Gr 3</u> 20m sprint 3.5 ± 0.1 vs. 3.3 ±0.1 CMJ 47.0± 3.0 vs. 47.6± 5.5 Predicted vertical power 3. 611,3± 327.3 vs. 4,141.3± 397.1 VO_{2max} 48.1± 3.4 vs. 52.2 ±3.5 <u>Group 2 vs. Group 3</u> 20m sprint 3.4± 0.2 vs.	

			Body mass 86.1 ±6.0 vs. 86.3± 9.4 Maturity offset 1.73 ±0.27 vs. 2.16 ±0.31 Sum of 6 skinfolds 81.0±25.0 vs. 77.8±20.8	3.3 ±0.1 CMJ 47.3± 4.9 vs. 47.6± 5.5 Predicted vertical power 4 081.5 ±454.9 vs. 4 141.3± 397.1 VO_{2max} 48.3± 3.6 vs. 52.2 ±3.5	
Darrall-Jones et al [79]	Group 1: U16 (n=29) Group 2: U18 (n=23) Group 3: U21 (n=15)	**Anthropometric**: height, body mass, sum of eight skinfolds **Physical:** 5, 10, 20, 40m sprint test, acceleration, velocity, momentum; agility 505; vertical jump; Yo-Yo IRT L1; 30-15 Intermittent fitness test; 3RM front squat, split squat, bench press, prone row, chin; isometric mid-thigh pull	<u>Group 1 vs. Group 2</u> Height 178 ±7.1 vs. 183.5± 7.2 (ES=-0.6) Mass 79.4 ±12.8 vs. 88.3 ±11.9 (ES=-0.7) Sum of 8 skinfolds 88.8± 41.9 86.7± 21.3 (ES=0.1) <u>Group 1 vs. Group 3</u> Height 178 ±7.1 vs. 186.7 ±6.61 (ES=-1.1) Mass 79.4 ±12.8 98.3± 10.4 (ES=-1.5) Sum of 8 skinfolds 88.8± 41.9 vs. 105.3± 35.4 (ES=-0.4) <u>Group 2 vs. Group 3</u> Height 183.5 ±7.2 vs. 186.7 ±6.61(ES=-0.5) Mass 88.3± 11.9 vs. 98.3 ±10.4 (ES=-0.8) Sum of 8 skinfolds 86.7 ±21.3 vs.105.3± 35.4 (ES=-0.7)	<u>Group 1 vs. Group 2</u> CMJ 33.5 ±4.8 vs. 47.1 ±3.6 (ES=-1.2) CMJ peak power 3.965± 650 vs. 4561 ±641(ES=-0.9) Agility 505 Lt side 2.51± 0.17 vs. 2.57± 0.12 (ES=--0.4) Agility 505 Rt side 2.54± 0.14 vs. 2.52± 0.13 (ES=0.1) Yo-yo IRTL1 1.144.6± 337.2 vs. 1.225± 373.8 (ES=-0.2) 30-15IFT 18.4 ±1.3 vs. 18.6 ±1.1 (ES=-0.1) ASR 3.84 ±0.52 vs. 4.04± 0.39 (ES=-0.4) 5m sprint 1.05± 0.09 vs. 1.06± 0.04 (ES=-0.2) 10m sprint 1.82 ±0.12 vs. 1.81 ±0.06 (ES=0.1) 20m sprint 3.10 ±0.19 vs. 3.09± 0.12 (ES=0.1) 40m sprint 5.66 ±0.37 vs.	

				5.51 ±0.24 (ES=0.5) <u>Group 1 vs. Group 3</u> CMJ 33.5 ±4.8 vs. 47.1 ±3.6 (ES=-3.1) CMJ peak power 3.965± 650 vs. 5.219± 606 (ES=-2.0) Agility 505 Lt side 2.51± 0.17 vs. 2.41± 0.10 (ES=0.7) Agility 505 Rt side 2.54± 0.14 vs. 2.37± 0.15 (ES=1.2) Yo-yo IRTL1 1.144.6± 337.2 vs. 1.243 ±326.1 (ES=-0.3) 30-15IFT 18.4 ±1.3 vs.19.0± 1.1 (ES=-0.5) ASR 3.84 ±0.52 vs. 4.06± 0.26 (ES=-0.5) 5m sprint 1.05± 0.09 vs. 1.07± 0.07 (ES=-0.3) 10m sprint 1.82 ±0.12 1.79± 0.10 (ES=0.3) 20m sprint 3.10± 0.19 vs. 3.07 ±0.13 (ES=0.2) 40m sprint 5.66± 0.37 vs. 5.43 ±0.21 (ES=0.7) <u>Group 2 vs. Group 3</u> CMJ 39.5 ±6.1vs. 47.1 ±3.6 (ES=-1.5) CMJ peak power 4.561± 641 vs. 5.219± 606 (ES=-1.0) Agility 505 Lt side 2.57± 0.12 vs. 2.41± 0.10 (ES=1.4)	

				Agility 505 Rt side 2.52±0.13 vs. 2.37± 0.15 (ES=1.1) Yo-yo IRTL1 1.225 ±373.8 vs. 1.243 ±326.1 (ES=-0.1) 30-15IFT 18.6 ±1.1 vs.19.0± 1.1 (ES=-.04) ASR 4.04 ±0.39 vs. 4.06± 0.26 (ES=0.0) 5m sprint 1.06± 0.04 vs. 1.07 ±0.07(ES=-0.2) 10m sprint 1.81 ±0.06 vs. 1.79± 0.10 (ES=0.3) 20m sprint 3.09 ±0.12 3.07± 0.13 (ES=0.1) 40m sprint 5.51 ±0.24 vs. 5.43 ±0.21(ES=0.3)	
Gaudion et al [80]	Group 1: U16 (n=40) Group 2: U18 (n=37)	**Anthropometry**: height, mass **Physical**: standing vertical jump, dynamic vertical jump, 20m sprint, agility, repeated sprints, 20m multi-stage fitness test, overhead squat, single leg Romanian deadlift, double lunge; push up	Group 1 vs Group 2 Height 183± 7.2 vs. 181.3 ±6.9 (ES=0.24) Mass 78.1 ±8.5 vs. 72.6 ±8.5 (ES=0.62)	Group 1 vs. Group 2 Standing vertical jump 62.8 ±7.9 vs. 57.4 ±8.3 (ES=0.64) Dynamic vertical jump Lt 75.2± 7.7 vs. 71.4 ±5.7 (ES=0.55) Dynamic vertical jump Rt 73.2± 8.5 vs. 65.9± 6.4 (ES=0.88) 20m sprint 3.06 ±0.09 vs. 3.11± 0.12 (0.47) Agility 8.45 ±0.25 vs. 8.58 ±0.28 (ES=0.77) Repeated sprints 26.89± 0.98 vs. 27.64 ±0.81 (ES=0.48) 20m MSF test 13.2± 1.0 vs. 12.6 ±1.2 (ES=0.27) Overhead squat 5.1± 1.2 vs. 5.4 ±1.1 (ES=0.27)	

				Single leg Romanian deadlift Rt side 4.2 ±1.4 vs. 3.8± 1.1 (ES=0.34) Single leg Romanian deadlift Lt side 4.1 ±1.4 vs. 3.8± 1.3 (ES=0.24) Double lunge Rt side 5.7 ±0.9 vs. 5.7± 0.9 (ES=0.08) Double lunge Lt side 5.8± 1.0 vs. 5.6± 1.0 (ES=0.16) Push up 5.5 ±1.1 vs. 4.9± 1.2 (ES=0.52)	
Kobal et al [81]	Group 1: U15 Group 2: U17 Group 3: U19 Group 4: Professional senior rugby players (PRO) Group 5: National team players (NAT)	**Anthropometry**: Height, mass, **Physiological:** Squat jump (SJ), countermovement jump (CMJ), zig-zag change of direction speed test (COD_45), proagility shuttle test (PRO_AGT), 10m, 20m and 40m speed test, yo-yo endurance test	Height (cm) U15: 169.7±12.1 U17: 177.2±8.7 U19: 177.0±7.1 PRO: 178.6±5.4 NAT: 179.2±6.7 No significant difference on height across groups Mass (kg) U15: 63.8±10.9 U17: 76.3±13.1 U19: 82.5±18.2 PRO: 93.1±13.8 NAT: 90±11.5 U19, PRO, NAT >U15 PRO, NAT > U17	NAT group had greater performance in both SJ and CMJ SJ (ES=1.26-2.96) CMJ (ES=1.48-3.14) PRO better than U17 grp SJ and CMJ SJ (ES=0.53) CMJ (ES=0.39) U15 had sign. lower values for both jumps than other grps NAT grp had lower agility times (ES=-3.08 to -1.76 for COD_45; ES=-5.11 to -1.75 for PRO_AGT) U15 grp had higher agility time in relation to other grps (ES=0.93 to 3.08 for COD_45; ES=1.12 to 5.11 for PRO_AGT)	

				PRO grp had shorter time than U17 (ES=-0.27) and U19 groups in the COD_45 (ES=-0.44) NAT grp had shortest sprinting time for 10m, 20m, 40m sprinting distances (ES=-2.76 to -0.33 for 10m; -4.5 to -0.9 for 20m; -3.37 to -1.06 for 40m U15 demonstrated the longest times (ES=1.66 to 2.67 for 10m; 2.80 to 4.50 for 20m; 1.73 to 3.37 for 40m NAT had the highest distance on Yo-yo endurance (ES=1.41 to 2.06) U15 had the lowest values (ES=-2.06 to-0.69)	

Appendix C: Second qualitative study

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BMC Research Notes

RESEARCH NOTE

Open Access

High-school adolescents' motivation to rugby participation and selection criteria for inclusion in school rugby teams: coaches' perspective (the SCRuM project)

M. Chiwaridzo*, G. Ferguson and B. C. M. Smits-Engelsman

Abstract

Objective: Despite increasing rugby popularity among schoolboys' worldwide, specific factors influencing their motivation to participate in rugby remain unclear. Therefore, this study was conducted in two parts with a dual purpose of exploring perceptions of rugby coaches on (i) factors motivating schoolboys to engage in competitive rugby, and (ii) criteria for selecting schoolboy rugby players for possible inclusion in school rugby teams.

Results: A qualitative study targeting Zimbabwean high school-based rugby coaches purposively-recruited during the 2017 Dairiboard Zimbabwe Rugby School Festival was conducted. Using the conventional approach to content analysis, the 22 recruited male coaches (median age = 45.5 years) felt that playing rugby is a choice largely influenced by either intrinsic or extrinsic motives for schoolboys. Additionally, coaches considered players' characteristics (performance during training, attitude, physical qualities and skills) and match-related factors when selecting schoolboys for possible inclusion in school rugby teams. To effectively promote competitive rugby participation among schoolboys and promote sustainable and effective talent identification programmes in Zimbabwe, more recognition should be paid to factors motivating schoolboys to participate in rugby and also on the factors coaches consider when assembling school rugby teams which indirectly informs on what coaches think should be trained among schoolboy rugby players.

Keywords: Adolescents, Motivation, Qualitative study, Coaches, Rugby, Zimbabwe, SCRuM

Introduction

Rugby union (rugby) is a popular sport among schoolboys worldwide [1–3]. Today, schoolboy rugby players are playing more competitive matches and have better physical attributes than before [4–6]. Studies points to increased physical demands of schoolboy rugby and high injury risk [7–10]. Still, schoolboy rugby continues to grow worldwide [1]. In Zimbabwe, the growth is evidenced by establishment of the "elite" Super Eight Schools Rugby League (SESRL) and the "sub-elite" Co-educational Schools Rugby League (CESRL) [4, 11]. However, little is known about factors influencing motivation to participate in competitive rugby from the coaches' perspective.

Several studies documented general reasons for sports participation for children, adolescents and adults ranging from weight management, social interaction to enjoyment [12–18]. Innumerable reasons cited illustrate complexity of the construct of motivation [18, 19]. One motivational theory, the self-determination theory (SDT) widely used to explain participatory behaviour [19, 20], is conceptually anchored on the belief that motivation is either intrinsic or extrinsic-oriented and driven by psychological needs for competence, autonomy and relatedness [21, 22].

Important to understand also is whether players' attitudinal attributes could be a selection strategy coaches

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use when assembling a school rugby team. Studies conducted to investigate rugby coaches' selection criteria of schoolboys are scarce. Previous studies showed that team selection is based on players' experience, and certain attributes [23–25]. However, this evidence is mainly from quantitative studies. Therefore, this study was conducted to explore perceptions of rugby coaches on reasons they believe motivate schoolboys to participate in rugby and strategies used for selection of school teams. This study is useful in Zimbabwe where schoolboy rugby is considered an "elite" sport popular in private and top government schools, and where inclusivity efforts to develop the sport in disadvantaged schools are underway. Practically, this study may inform development of strategies to increase participation rates among schoolboys. Moreover, results on selection criteria may inform coaches on qualities important for rugby from the coaches' perspective.

Main text

Research design, setting and participants

A qualitative study was employed for this study. This study was part of a broader project called the School Clinical Rugby Measure (SCRuM) partly described elsewhere [11]. Data collection was conducted at a school hosting the 2017 Dairiboard Zimbabwe Schools Rugby Festival (DZSRF). The festival was a 7-day long tournament featuring 150 high-schools. Coaches were selected with an *apriori* intention of maximum heterogeneity within the sample. This entailed purposively recruiting coaches from three high-school rugby leagues in Zimbabwe, namely SESRL, CESRL and Interscholastic High Schools Rugby League (IHSRL, "amateur league") [11]. Full-time rugby coaches with at least 5 years' coaching experience were eligible.

Procedure

Ethical approval was granted by the University of Cape Town Human Research Ethics Committee (HREC ref: 016/2016). Coaches were approached by the first author, and interview appointments set with willing coaches. Written informed consents were provided. Subsequently, a trained research assistant conducted semi-structured, one-on-one interviews in a quiet classroom using an English interview guide [26]. All interviews were audio-recorded and lasted between 15 and 40 min. The recordings were then transcribed verbatim. Participant checking of the transcripts was conducted with a convenience sample of participants (n = 12) checking accuracy of the transcripts.

Data analysis

A conventional inductive approach to content analysis [27] following steps of "decontextualisation", "recontextualisation" and "categorisation" as described by Bengtsson [28] was used for theme generation. This entailed reading the transcripts, extracting and condensing meaning units, data coding, formulating categories and themes. This approach allowed themes to flow from the data [27] and was chosen because of limited literature explaining schoolboy participation in rugby and coaches' selection criteria. Data analysis was manually completed by the first author and subsequently triangulated by an independent person.

Results

Sample characteristics

The coaches' demographic and work-related data are presented elsewhere [26]. Briefly, 22 coaches were interviewed. The majority had ≥ 10 years coaching experience and were mainly coaching senior schoolboys from private schools playing in the SESRL.

Motivation for the participatory behaviour

Coaches' perceptions on factors motivating schoolboys' participation in rugby yielded one over-arching theme ("*It is a choice to play rugby*"). Schoolboys are motivated by intrinsic (personal preference, enjoyment, and nature of the sport) or extrinsic factors (influence from significant others, professional ambitions, emulation and monetary rewards) (Additional file 1).

Intrinsic factors Most coaches felt that rugby is a personal preference.

> *"The sport is open to every child [...]. Any child who wants to play, we encourage them to join in and play. [...]. Our own Ministry of Primary and Secondary Education [...] mandates every child to participate in sport…." (Participant AW01).*

> *"You know rugby is a sport for everyone, not just for the 30 players you see running around for the ball in the pitch…" (Participant STG01)*

Some indicated that schoolboys are motivated by enjoyment and passion.

> *"I think what motivates these youngsters to play rugby is passion for the game, the kids enjoy the sport [...]. If you consider how dangerous the sport [...] and still you have 30, 40 kids coming and say they want to play rugby. That is passion." (Participant CBC01).*

> *"I remember asking one Under-16 rugby player, after he walked out of a competitive match last year, why he is still interested in playing rugby*

after having a fracture of collarbone. He said to me rugby is everything to me; it's all I feed on every day. I read, sleep and talk rugby...." (Participant MF01).

Schoolboys were also said to be motivated by the nature of the sport (physicality, accommodativeness and spectator magnetism).

"....watch when my boys play School A, it's like war, [....], and most students who come for rugby [...], probably enjoy the adrenaline rush that comes with tough and competitive sports..." (Participant AW01).

"....which sport can accommodate players of different sizes of people like rugby. You see very fat kids play rugby, very thin kids playing rugby and in-between players playing rugby...." (Participant LOM01).

"....so that excitement of playing competitive rugby, in a sport that attracts a huge crowd at the school is probably overwhelming [....] and makes them want to play rugby for the school." (Participant F01).

Extrinsic factors Professional ambitions, emulation and monetary rewards were also mentioned.

"....most of these boys [...], play rugby with the hope [...] that they will play professional rugby [...] and probably make a lot of money. That mentality drives their passion [...], and they feel motivated to want to play rugby." (Participant MF01)

"....we have the likes of coach X, who came through the junior ranks at this school [...], played outside Zimbabwe and now they are back coaching these kids. That is strong motivation for the kids...." (Participant PE01)

External influences were also cited.

"...some are dragged by others, especially if you look at the U13s....." (Participant ES01).

"There are also other influences [...] from parents who used to play the sport when they were young, or used to enjoy watching the sport...." (Participant AW01).

Selection criteria

Analysis of the factors coaches consider for selection of schoolboys into teams yielded two overarching themes (Additional file 2).

Theme 1: "It is about the player" Most coaches consider players performances during training.

"The youngsters that have been brilliant in training, working very hard during training as seen by the coach probably get a nod to play." (Participant PE02).

Furthermore, attitudinal traits such as motivation were highlighted.

"I choose players that are hard-working [...], and rugby is a principled sport, so we expect the boys to have principles, to show that they are committed, motivated to play and have discipline..." (Participant ER01)

Some considered fitness, physical qualities and rugby skills.

"..... But of course they have to have the physical qualities and the skills that important in rugby, and they have to be injury-free." (Participant P01).

"The sport is for the strong [....], there is a degree of physical fitness that we expect all rugby players to have, minimum physical fitness [...]" (Participant MF01).

"...but certainly we would pick players who can run, who can hold the ball, pass and score [....]players who are strong to tackle, [....], players who can fight to win possession of the ball...." (Participant ES02).

Theme 2: "It's about the match" Some coaches felt that team selection is circumstantial, factoring in the impending competitive match

"I try to go for players whom I know will give me a win, a balanced team [...]. So the team must be balanced...." (Participant ER02).

"......So as a coach, you need to have good knowledge of your opponents, their strength and weakness and form strategise and see which players from your team you need to include in the team." (Participant STG01).

Discussion

This study explored factors coaches believe motivate schoolboys' participation in competitive rugby and strategies to select them for school rugby teams. Unlike most studies [15, 18, 19], this study uniquely sought coaches' perceptions. Coaches represent an important stakeholder in continued rugby participation by schoolboys. Additionally, by virtue of their experience and multifaceted roles as recruiters, trainers, and team selectors, coaches have keen insight into schoolboys' motivation. They offer unique perspectives which may guide the development and implementation of strategies to improve schoolboys' participation rates.

The main finding of this study shows that coaches have different reasons explaining participation in rugby. Motives range from personal preference, enjoyment, passion, nature of the sport, professional ambitions, influence from parents and friends. This diversity highlights complexity of the construct of motivation [29]. Our results also seem to imply that schoolboys' participation is an individualistic decision underpinned by intrinsic or extrinsic factors and aimed at realising certain goals. This is the foundational basis of the SDT [18, 21, 22, 30]. The theory assumes that human behaviour is driven by psychological needs of "competence", "autonomy" and "relatedness" [21]. Our results support the conceptual principles underpinning SDT. For example, the need for autonomy is evidenced by the independent decision making to engage in competitive rugby. Additionally, the need for relatedness as described in literature [22] helps us understand the influence of significant others in motivating schoolboys.

Although there are no studies documenting coaches' perceptions on factors motivating schoolboys to participate in rugby, our results are consistent with studies investigating general sports participation among children, adolescents and adults [12, 14, 15, 17, 18]. A study conducted using college students' found that enjoyment and the need for challenges were predominant motivational factors for sport participation [12]. A narrative review of studies involving children, adolescents and adults corroborated the findings [15]. However, our results also show that there are unique motives for rugby participation among schoolboys facilitated by contextual, environmental and rugby-related factors. Sports are compulsory in Zimbabwean schools and schoolchildren partake in rugby by choice regardless whether they are selected or not for competitive matches. In such contexts, participation is driven more by passion and love for the game despite the physical challenges inherent in the sport. Additionally, issues around masculinity and physicality were also expressed as motivating factors. This is linked to the nature of sport which requires a show of masculine ego and physical attributes commensurate with rugby demands [5–8]. Extrinsic motivational factors such as professional ambitions, monetary rewards were also identified. Similarly, they have been reported elsewhere [13, 31] and reflect contextual and socio-cultural perceptions people have towards the sport.

The study also explored coaches' criteria when selecting schoolboys for inclusion in school rugby teams. Coaches largely select based on training performances, players' attitudes, physical fitness, physical qualities, and possession of basic rugby skills. This variability indicates different coaching ideologies and guiding principles for team selection. These findings are supported by previous studies and reflect the nature of the sport which requires technical competence and well-developed physical attributes [23–25]. To achieve that expertise, training is required and this explains value placed on training performances by coaches; a finding shared by Baker et al. [32].

Limitations

- This study did not interview schoolboy players. Future studies may want to triangulate these findings using them.
- Data analysis was not conducted iteratively based on the saturation concept. Therefore, it is not clear if saturation was reached with 22 participants included in the sample.

Additional files

Additional file 1. Emergent codes, categories and themes from participatory behaviour data from interviewing high school adolescent rugby coaches.

Additional file 2. Emergent codes, sub-categories, categories and themes from the interview data on coaches' selection criteria.

Abbreviations

CESRL: Co-educational School Rugby League; DZSRF: Dairiboard Zimbabwe School Rugby Festival; IHSRL: Interscholastic School Rugby League; HREC: Human Research Ethics Committee; SESRL: Super Eight School Rugby League; SCRuM: School Clinical Rugby Measure; U: under.

Authors' contributions

MC, BCMSE and GF originally developed the concept and design of the study. MC is a 4th-year doctoral student at UCT and this manuscript is part of his doctoral thesis. MC acted as the lead investigator under the guidance, mentorship and supervision of BCMSE and GF. MC conducted the literature review, recruited participants and conducted the initial data analysis with further triangulation of the coding, categorisation and theme formulation with variable assistance coming from other people who were acknowledged in the acknowledgment section. MC drafted the manuscript for publication and acted as the corresponding author. BCMSE and GF performed critical revision of the manuscript, provided extensive revisions prior to submission to the journal for review. All authors read and approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests.

Availability of data and materials
The datasets generated and/or analysed during the current study are not publicly available due to the fact that the data is part of ongoing research. However, the data are available from the corresponding author on reasonable request.

Consent for publication
Not applicable as the manuscript does not contain any data from any individual person.

Ethics approval and consent to participate
This study adhered to ethical principles under the Declaration of Helsinki. Institutional access and permission to conduct the study at the school hosting the Dairiboard Zimbabwe Schools Rugby Festival was obtained from Ministry of Primary and Secondary Education (ref C/426/3), Harare Province Education Director Office, and from the respective school headmaster. Ethical approval was sought and granted by the Human Research Ethics Committee (HREC) of the University of Cape Town (ref: 016/2016) and, locally from Medical Research Council of Zimbabwe (ref: MRCZ/A/2070). Participants provided written informed consent prior to participation following a verbal explanation and reading an information letter explaining the rationale and all procedural issues regarding the study.

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Appendix D: Human Research Ethics Committee (HREC) ethical approval

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
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12 January 2016

HREC REF: 016/2016

Dr G Ferguson
Physiotherapy
Health & Rehab
F-floor, OMB

Dear Dr Ferguson

PROJECT TITLE: SCRuM: SCHOOL CLINICAL RUGBY MEASURE. WHAT MAKES (OR BREAKS) A GOOD ADOLESCENT RUGBY PLAYER? (PhD Candidate Mr M Chiwaridzo)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

We hereby confirm that the above-mentioned protocol application has been submitted to the HREC for review.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that no research may occur without formal ethics approval.

Please quote the HREC REF in all your correspondence.

Yours sincerely

Signature Removed

PROFESSOR MARC BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Approval for change of title following ethical clearance

D9 – Approval of Change of Title - 2015

University of Cape Town

Faculty of Health Sciences

Form D9: Approval for Change of Title

Please complete and return to Vuyi Mgoqi (Vuyi.Mgoqi@uct.ac.za) in the Postgraduate Office

Name and student no	Matthew Chiwaridzo CHWMAT001
Degree name (e.g. MSc(Med) in Physiology)	PhD Physiotherapy
UCT Student Email address for correspondence	chwmat001@myuct.ac.za.
Student signature:	Signature Removed
Date:	03/05/2019

Qualifications	MSc Physiotherapy
Old Title	SCRuM (School Clinical Rugby Measure); What makes or breaks a good adolescent rugby player?
Proposed new title	Development and Validation of the School Clinical Rugby Measure (SCRuM) Test Battery: Understanding the qualities or skills defining a good male adolescent rugby union player
Proposed title change supported by Departmental Research Committee (DRC)	Name of Chair, Department Research Committee: Dr Gillian Ferguson pp Michal Harty Signature: Signature Removed

Please give reason for the need for to change your thesis/dissertation title:

This application for a change of topic follows a recent approval of our protocol amendments which proposed the removal of the last phase of our research project. This last phase entailed conducting a prospective assessment of male adolescent U19 rugby players in order to ascertain the factors predicting the risk of injury among players playing competitive rugby. This study was meant to provide detailed information on the physical, physiological qualities or game-specific skills likely to "break" good adolescent rugby players. The removal of this phase in the project has necessitated this change of topic as we are no longer evaluating injury risk. Now, the just approved protocol amendments proposed the inclusion of test-retest reliability and construct validity of the test battery in the last phase of the research project. So, we are proposing changing the current title to the one proposed above largely to suit our methodological procedures.

I support / do not support the thesis/dissertation title change as requested by this student			
Supervisor name and signature:	Name: Dr Gillian Ferguson	Signature: Signature Removed	Date: 3/5/2019
I recommend / do not recommend the thesis/dissertation title change as requested by this student			
HOD name and signature	Name: A/Prof Lebogang Ramma	Signature: Signature Removed	Date: 6/5/19
I approve / do not approve the thesis/dissertation title change as requested by the above student			
Deputy Dean: Postgraduate Affairs:	Name:	Signature:	Date:

For office use:

Appendix E: Information letter and informed consent for the qualitative study

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Dear Coach,

My name is Matthew Chiwaridzo. I am a PhD student at the University of Cape Town in the Department of Health and Rehabilitation Sciences, Physiotherapy Division in South Africa. I am conducting a research project entitled: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player***". My research team includes my supervisors: Professor Bouwien Smits-Engelsman and Dr Gillian Ferguson from University of Cape Town, and research assistants from the University of Maastricht in the Netherlands and from the University of Zimbabwe. I would like to invite you to participate in my research study. To help you make an informed decision regarding your participation in this study, I have prepared some information for you below.

PURPOSE OF THE STUDY

This study will be conducted in three continuous phases. The purpose of this part of the study is to determine qualities and skills needed in adolescent rugby from local school rugby coaches and to find commonly-used tests by coaches to measure the identified qualities and skills. This information will help us in developing a test battery called the SCRuM which will include all the tests for the qualities and skills identified by the local coaches in this study as important in rugby. By knowing the skills and qualities needed in rugby, local coaches like yourself will know what to train more to produce competent young rugby players.

WHY HAVE I CONTACTED YOU?

I have contacted you because you are currently working as a high school rugby coach in a school that has rugby as a sport or you are coaching a school that is competing either in the Super Eight Schools Rugby League or the Co-educational Schools Rugby League. Your experience as a rugby coach is very important to this study. The schools participating in this study were either purposively-selected for this study from the schools competing in the two domestic leagues or were randomly chosen from a pool of other schools having rugby as a sport but not competing in the elite leagues. You happen to be a coach in one of the selected schools.

WHAT WILL YOU BE ASKED TO DO?

A one-on-one interview will be conducted. This will probably take 20 minutes of your time. The first part of the interview will ask you demographic and rugby-related information to understand your background and rugby experience. The second part of the interview will ask you questions related to the qualities and skills which you think are important in rugby. The interview will be recorded for further analysis by the research team. However, all the information you provide will only be used for the purpose of the study. Please feel free to indicate to us the place, time and date agreeable to you for the interviews to be conducted.

ARE THERE RISKS INVOLVED?

There are no risks involved with the study since the study involves answering questions in an interview format. There are no right or wrong answers. Feel free to express your opinion explicitly regarding the qualities and skills needed in rugby. The researcher will value and respect all your contribution and will not judge you based on your answers. The researcher may ask further questions to seek clarity on any answer you provide.

WHAT WILL I GET IF I TAKE PART?

There is no payment for taking part in the study. I hope at the conclusion of this study the information gathered will benefit you, your school and the nation at large in knowing the skills and qualities to look for, to train in young adolescent male rugby players, and the tests that coaches can use to screen for talented rugby players and for players with increased risk of getting injured.

IS PARTICIPATION VOLUNTARY?

Participation in the study is entirely voluntary. You are not under an obligation to participate. Your refusal to participate will be respected and no repercussions will follow that and there is no need to provide an explanation. You have no obligation to remain in the study or participate in subsequent follow-up studies to this one conducted at your school. You can withdraw at any point without consequences or the need to provide an explanation.

WILL PEOPLE KNOW WHAT ANSWERS I HAVE GIVEN?

No one will know what answers you gave except the researchers. All the information obtained from you will be used specifically for this study. To ensure your confidentiality, the interviews will be completed in a private room free from noise and disturbances. You are encouraged not to discuss your answers or consult with other coaches after reading this letter or even after the interview. Your name or school name will not be given to anyone and will not be listed anywhere. The audiotapes will be handled as sensitive material by the research team and will be handled with due care after the interview. They will be kept in the principal investigator office at the University of Zimbabwe, College of Health Sciences at Parirenyatwa hospital in the Department of Rehabilitation in a locked cupboard for the period of the whole study (3 years). The information will only be destroyed two years after the conclusion of the study. However, the results of this project will be made available to the schools that participate through a copy of the binded thesis. The results will also be published in journals for the global audience but will not be linked to you in any way.

IS THE STUDY APPROVED?

I have been given ethical approval by Human Research Ethics Committee in South Africa and the Medical Research Council of Zimbabwe to conduct the study. These committees make sure that people who take part in research are protected. I have provided contact details for these ethical committees at the end of this information letter in case you want to verify the details of this study. I have also obtained institutional approval from the Ministry of Primary and Secondary Education and your school headmaster to conduct the study at this school.

WHO TO CONTACT FOR MORE INFORMATION?

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. For more queries, you may contact the Faculty of Health Sciences, Human Research Ethics Committee (+27 21 406 6338) through their chairman, Professor Marc Blockman, for any questions or concerns regarding your rights or welfare as a participant in this study. Locally, you can contact the Registrar at the Medical Research Council of Zimbabwe on the following numbers +263 4 791792. Should you have any questions regarding the study, you may contact the principal investigator (Matthew Chiwaridzo) on the following number +263 773 603 069 or through email at matthewchiwaridzo@yahoo.co.uk. My physical address is **University of Zimbabwe, College of Health Sciences, Rehabilitation Department, Room 41, Ground Floor, New Health Sciences Building, P.O Box A178 Avondale, Harare, Zimbabwe**. You may also contact my supervisor, Professor Bouwien Engelsman on bouwiensmits@hotmail.com. Additionally, contact my co-supervisor from the University of Cape Town, Dr Gillian Ferguson at this email address, gillian.ferguson@uct.ac.za or at the following physical address as well, **Division of Physiotherapy Department of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town**, Tel: +27 21 406 6045.

Your cooperation is greatly appreciated. If you chose to participate, please sign the attached informed consent form.

Yours faithfully,

Matthew Chiwaridzo

Signature……………………………………………..

Date…………………………………………………..

<u>Informed consent form</u>

	School of Health and Rehabilitation Sciences **Faculty of Health Sciences** Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Study title: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***.

Institution: *University of Cape Town, Faculty of Health Sciences, Division of Physiotherapy*

I --have read the information sheet given to me by Matthew Chiwaridzo. I understand he is conducting a research study. I understand what is required of me and I have had all my questions answered. I do not feel that I am being forced to take part in this study and I am doing so on my free will. I know that I can withdraw at any time if I so wish and that it will have no bad consequences for me.

Signed:

---	---------------------------------------
Participant	date and place
--	---------------------------------------
Researcher	date and place
--	---------------------------------------
Witness	date and place

Thank you very much for your support

Appendix F: Interview guide

	School of Health and Rehabilitation Sciences **Faculty of Health Sciences** Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Participant Reference Number…………………………… Date………..……….

Section A: Demographic and school-related information

1. How old are you? (Full years attained):
2. What is the name of your school?
3. What type of school is it?
4. In which high-school rugby league does your school participate?

Rugby-coaching related information

1. Overall, how many years in total have you been a high-school rugby head coach?
2. When did you start coaching rugby at this particular school as a head coach?
3. Which school team(s) are you currently coaching at the present moment at the school?
4. For how long have you been coaching this current school team(s)?
5. Which other rugby school team(s) have you been previously involved with either as a head coach or assistant coach at this school before?
6. Do you have any other rugby coaching experience besides in high schools?
7. If yes, please specify where else you have coached previously

Personal rugby experience

8. Have you ever played rugby in your lifetime?
9. For how many years in total did you play rugby?
10. At what level did you play rugby?

Section B: Qualities needed in rugby

This section elicits information on the qualities you think are needed in rugby especially by male adolescents among other important questions.

First part of the interview: Source of rugby players and criteria for player selection

1. What do you think motivates high school boys to take up rugby as a sport in school?
2. Where do the young adolescent players who get to play high-school rugby at your school come from?
3. Who selects the players to be included in the school rugby teams at each playing level from the Under 13 to Under 19?

Second part of the interview: Qualities important in rugby

1. What individual qualities, attributes, or skills do you consider extremely important in defining/characterising a good adolescent rugby player?
2. Given an opportunity to participate in talent identification and recruitment programme in Zimbabwe, what individual qualities, attributes or skills would you consider or look for among young potential players?
3. Give me one example of a rugby player in your school team you consider exceptionally good in playing rugby, explaining why you think he is such a good young player in terms of the qualities, attributes or skills he possesses?

Third part of the interview: Methods of assessing identified qualities

1. For each quality, attribute or skill you identified to be defining a good adolescent rugby player and important to consider for player recruitment, what test(s) or methods of assessment do you frequently use to assess for those qualities among your players?

Appendix G: Emergent themes with selected illustrative quotes

Theme	Category	Sub-category	*Emergent Codes	Selected illustrative comments from coaches
Physiological characteristics	Muscular strength	Total body strength	Strong, strong body, strength, sturdy	*"..rugby is a man's game you need to be strong, it involves a lot of contact, which is aggressive and requires players that are able to resist the pushes, the pulls and tackles. You need to be strong"* ***(Participant MF01)***
		Upper-body muscular strength	Forearm, arm, hand, neck, shoulder, and trunk strength	*"So you need strength in your neck muscles, shoulders, forearms, arms and hands and wrists. Shoulder strength helps [...] with high and low tackles, [...] forearm and arm strength plus trunk enables you to push hard through defensive walls, hands and wrists strength holds the ball tight whilst running, in catching and in passing..."* ***(Participant AW01)***
		Lower-body muscular strength	Lower leg strength, thigh strength	*"Thigh strength gives you speed to push through, in scrums it helps forward players scrummage. Lower leg strength is important for running and I think especially for adolescents because their rugby is mainly running a lot they need lower strength, and power, strength in these muscles and in the calf muscles as well for your sprints"* ***(Participant AW01)***
	Muscular power	Total muscular power	Power, powerful	*"Forwards spend a lot of time wrestling for the ball, they get into tackles, so they need balance, strength and power and good vision and good communication skills with each other."* ***(Participant DZ01)***
		Upper-extremity power	Arm-power	*"I think you need strength, and arm power to play through defenders whilst running, holding the ball but they must also be lean enough to carry their body, to run…"* ***(Participant HE01)***
		Lower-extremity power	Leg power	*"Rugby is physical from the U13s to the U19s. It's about power to make tackles, resisting tackles, all the aggression, power in sprinting, power in our legs during lineout and when going for kicked balls"(****Participant STJ01)***
	Agility	Agility	Change of direction, agility	*"…agility as well is important in all players especially for wingers, flanks, and eighth man. Agile players often evade defenders smoothly and run down the defensive line and make a break. Because in rugby [...] you can score from a wide position [...], so change of direction is crucial."* ***(Participant DZ01)***

	Endurance	Endurance	Endurance, aerobic capacity, indefatigable, stamina	*"... young players need endurance, it is very important. I would say the number one quality is endurance, because you can imagine form one students Under-13 players running around, for 40 minutes or form fours your Under-17 running for 70 minutes with only a 10minutes break."* ***(Participant AW01)*** *"You know if you are not fit, physically fit, it takes about 5 minutes and you are tired already, you cannot run anymore and your legs are getting cramps and you can't continue, juts 5minutes only and you are done, so you need to be fit, you need to be very healthy, and show that you have aerobic and anaerobic capacity"* ***(Participant STJ01)***
	Speed	Speed	Ability to accelerate, run, running ability, fast, good speed , sprinting	*"I also look at speed, for all players. Although there are certain positions which require speed than others but every rugby player must demonstrate the ability to run, accelerate when need arises, when in situations of attacking and defending."* ***(Participant AW01)*** *"If you don't have the speed, and the strength and the ability to tackle well, then you are doomed. The opponents will beat you"* ***(Participant F01)***
		Repeated running	Keep running, continued running, speed endurance, repeated running	*"So speed is important and young players should demonstrate ability to run over and over several distances whether short or long without getting tired for them to enjoy rugby.*" **(*Participant DZ01)*** *"Good players ought to have speed and show that they can run without easily getting tired. There is less time to rest in rugby but most of the time its speedy running, its tackles, and the hard stuff." (***Participant CBC01***)*
	Anaerobic capacity	Anaerobic capacity	Anaerobic capacity, recovers well, recovers from high intense activities	*"…that ability to recover from the high intense activities and be able to quickly rest and quickly resume working under pressure in tackling, scrums, rucks and maul and to work when tired is crucial in rugby." (***Participant STJ01)*** *"Good rugby players at all level must have exceptional anaerobic capacity should be able to participate in high intensity activities continuously without showing signs of fatigue and so do that effectively"* ***(Participant PE02)***
	Balance	Balance	Balance, stay on feet	*"And also they need to have strength as well, you need to have muscle, to be powerful because you get involved in collisions and you fall to the ground*

				you get tackled and so forth so you need to have stamina, that strength and balance so that you don't just fall" ***(Participant C01)***
	Coordination	Coordination	Hand coordination	*"So with speed, comes power, comes agility, comes flexibility and coordination as well, so you need all those qualities put together. Those are the major ones. I think"* ***(Participant ER01)***
	Muscle flexibility	Muscle flexibility	Flexibility	*"Yes, you also need muscle flexibility, balance, as well as coordination, endurance, speed, you should be able to accelerate and also decelerate and also be able to change direction without losing your balance."* ***(Participant LOM01)***
	Repeated effort ability	Repeated high intensity effort	Repeated engagement in physical battles, scrummaging, running, tackling	*Rugby is about continuous engagement in physical battles, your scrum, your ruck, during mauls, it's about fighting for the ball, sprinting with it, with little time to rest or recover fully so if you are a forward player so you need to be attentive."* ***(Participant HE02)*** *"Rugby is about running and you need to have the ability to continuously perform the physically challenging tasks such as running, tackling, scrummaging, for you to play rugby."* ***(Participant ER02)***
Anthropometric variables	Physical qualities	Body mass	Appropriate body mass, optimal mass, body weight	*"Every good player should be able to pass the ball [...] and rugby players also need to have strength and power, appropriate height, and body mass which depends on the position they play."* ***(Participant C02)***
		Height	Appropriate height, stature, tall height, short height	*"...also good players must have the height, body mass which is needed in the sport. Size is important for proper positioning of the player. [...] a good player uses the physical qualities he has to the advantage of the team..."* ***(Participant LOM01)***
		Body composition	Lean mass , muscular, muscle, optimal body	*"You also need players who have a good balance of muscle and fat, not too much fat not excessively thin rugby players but players with optimal body composition especially considering they position they fancy playing"* ***(Participant STG02)***
Game-specific skills	Basic technical skills	Passing	Accurate passing, good passing, passing credibility, purposeful passing	*You see players that make it to the highest level like myself have good skills, skills such as offensive skills, defensive skills, evasion skills, perceptual skills, being in the game the entire 70 minutes, good auditory and visual*

			skills, good passing skills this is important for every position" ***(Participant ES01)*** *"In addition, skills are important, rugby is a technical sport so players who can pass the ball accurately, pass at the right time [...] are good players"* ***(Participant AW01)***
	Kicking	Good kicker, kick, kicking for distance	*"To me, it's not about the size of the players, their appearance, no; it's about the skills, ball distribution skills, ball control after catching the ball, kicking and passing, tackling as well."* ***(Participant STG01)*** *"Where you need strength have players that are strong, where you need speed have players that have speed, but all rugby players must have the core skills of passing, catching, and kicking the ball…"****(Participant C01)***
	Catching	Catch, catching skills	*"Another skill that you need to be called a good player is catching. How you hold your hands to receive the pass, and then that ability to catch it is important. You begin to appreciate the importance of catching when your team is running to score a try and then someone miscatches a good pass, and the ball is taken away..."* ***(Participant F01)***
	Tackling	Effective tackles, good tackler, tackle correctly, tackling	*"Others include, good and effective tackle technique is important, all players need that, rugby is about bringing your opponents down and that must be done safely and to stop the ball from going forward."* ***(Participant PE01)*** *"But I would want all my players to have skills which are specific to rugby, because all rugby players have to kick the ball, have to pass, they should tackle and they should catch, they should control the ball, you know."* ***(Participant STG01)***
	Evasion	Beat defenders, evasion skills, evade opponents, side stepping ability	*"I would also want kids with skills, skills are becoming very important in rugby, and skills are a like the cherry on top of the ice cream, you need skills to evade defenders…"* ***(Participant HE02)*** *"If you look at U13 or U14, you don't emphasise on acquiring strength, muscles and power, their rugby is different when compared to the U18 [...] which is very physical or competitive, for the youngest players all what they really need is to be physically fit and have more of the technical skills for example, the kicking, the passing, evasion skills…"* ***(Participant P01)***

		Ball handling skills	Ball carrying, handling, shielding	*"But of course, these are higher skills, but all rugby players should have basic skills first such as passing, catching, kicking, tackling, running, and carry the ball."* **(Participant MF01)** *"…if we are at the grassroots level let's say we are in Binga there, your lower your standard a bit, you just want kids who can display the core rugby skills, can they pass, can handle the ball, can they receive a pass, very general rugby skills because you are considering that this a resource-constrained environment."* **(Participant ES02)** *"I think you also need very good passing skills, passing while running and very vision and quick thinking, as you run, and also good catching of the ball, shielding it whilst running…"* **(Participant HE01)**
		Offensive and defensive skills	Defensive abilities, offensive skills	*"Good rugby players are excellent in preventing scoring of tries, they should have good defensive and offensive abilities and all rugby players should be able to defend not just the backline players even the forward players they initiate the first team defence through offense so should be good with their defensive and offense play."* **(Participant C02)**
	Perceptual-cognitive skills	Auditory skills	Auditory perception, auditory skills	*"You see players that make it to the highest level like myself have good skills, skills such as offensive skills, defensive skills, evasion skills, perceptual skills, being in the game the entire 70 minutes, good auditory and visual skills..."* **(Participant ES01).**
		Visual skills	Good vision, visual acuity, watching the ball, vision	*"This is important, and for first team and second team players we emphasise during training the importance of vision, visual acuity and quickness in reacting to situations."* **(Participant LOM01)**
		Anticipatory skills	Anticipation, read intention of others, quick reaction to situation,	*"….we also wants players with very good anticipation […]. Players able to watch and read the game, see what is happening, and can anticipate what the opponent player wants to do* **…."(Participant P01)** *"I would choose one the guys who plays prop, MD an upper six student, he has been playing prop since U13, and he has grown into a mature and complete player with the prerequisites, he is an exceptional player with very good vision, strength and good anticipation."* **(Participant HE01)**

	Decision making	Decision making, thinking fast	*"Like strength is important, so as good side-stepping, evasion skills, tackling, running and passing, you also on top of that want a player with good decision making and someone willing to play with others"* ***(Participant HE02)*** *"Players who are aware of the next player around them, whether it's his player mate or not, and makes good decisions with the ball."* ***(Participant AW01)***
	Game sense	Alertness, reading game, understanding game, game sense, game awareness	*"I think what makes a good adolescent rugby player is not just passing and kicking, it's how you evade defenders, the tries you convert [...], how defensive you are, how you read the game and the ability to convert a loss to win through your individual skills."* ***(Participant MF01)*** *"Also knowing where to position yourself in important, a good player should always have at the back of their mind where the next person, who is the next person close to them, whether it's their player or opponent. This is important, this is understanding the game.* ***(Participant PE01)***
	Adaptability	Adapt to game situations, adapts quickly	*"….you knows it is an advantage to have a player who adapts to the game and can understand how various positions are played….."* ***(Participant CBC01)***
Miscellaneous	Communication	Communication skills	*"Rugby is about skills, so rugby players should be able to pass the ball, kick the ball, to tackle, to side step, to catch the ball, aim at a target and, also in all that rugby players should be able to communicate their body language their intentions and be able to read the intentions of others as well."* ***(Participant C01)***
	Leadership	Command respect, directs play, encourages team	*"The reason why i think he is exceptional is because he plays his position very well, and he is a tactical player with a lot of strength and power. He commands respects from the boys and he is very good leader for the team during play…"* ***(Participant C01)***
	Competitiveness	Competitive, fight for possession, fight off tackles	*"One example would be MD; he plays for seconds and subs for the first team. His is the eight men for the team. He has good speed, and he works very hard, he fights for every ball and he does not stop fighting."* ***(Participant HE02)***

		Team player	Belief in team work, cohesion, team work, team player	*"But we would look at team work, ability to work in a team…"* ***(Participant HS01)***
Psychological qualities	Mental strength	Mental strength	Mental strength	*"We look at mental strength, rugby it's a mental game and you need to have mental fortitude to go through the game…."* ***(Participant MF01).***
	Emotional stability	Emotionally stable	Emotionally stable	*" …. You need to be emotionally stable, physically fit and have the skills to play as a good player……"* ***(Participant ES01).***
	Attitude and personal traits	Positive attitude	Mentality to win, right attitude, positive attitude	*"I would want players that endure [….] players with the mentality to win [….] and who work hard not to lose."* ***(Participant ES01).***
		Courageous	Courage , courageous, bold, confident,	*"That's why am saying be courageous, dont be afraid to play with bigger players…."* ***(Participant ES02).***
		Determined	Determination, hard work, commitment, focussed, focus, motivated	*"You see it through hard work, determination […] if you are rugby player it should reflect on the pitch and even outside…."* ***(Participant P01)***
		Disciplined	Discipline, well-behaved	*"…..the right behaviour is important. You cannot mix rugby with girls you know, so you have to be [….] and well-disciplined to play rugby."* ***(Participant PE03).***
		Teachable	Easy to teach, listens, follows instructions	*"Good rugby players' listens to the instructions of their coaches on and off the pitch, they are teachable and are able to receive the instructions non-judgemental and unconditional and apply it in training and in competitive matches. This behaviour is important"* ***(Participant AW01)***
		Passionate	Heart for the game, interest, love, passion	*"Of course, I also consider things like do you have passion for the sport, rugby requires passion and love for the game. You may get injured for life so you have to love the game if you to excel and become a good player. Its love that makes you train hard and play hard as well"* ***(Participant CBC01)***

*Reflects all the codes that emerged from the interview data that were then sub-categorised and then categorised to form common themes. For example, for the theme of physiological characteristics under the category of muscular strength a number of codes emerged such as strong, strong body, strength and sturdy which were then coalesced and sub-categorised under total body strength

Appendix H: Systematic review protocol

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Systematic Reviews

PROTOCOL Open Access

A systematic review protocol investigating tests for physical or physiological qualities and game-specific skills commonly used in rugby and related sports and their psychometric properties

Matthew Chiwaridzo[1,2*], Gillian D. Ferguson[2] and Bouwien C. M. Smits-Engelsman[2]

Abstract

Background: Scientific focus on rugby has increased over the recent years, providing evidence of the physical or physiological characteristics and game-specific skills needed in the sport. Identification of tests commonly used to measure these characteristics is important for the development of test batteries, which in turn may be used for talent identification and injury prevention programmes. Although there are a number of tests available in the literature to measure physical or physiological variables and game-specific skills, there is limited information available on the psychometric properties of the tests. Therefore, the purpose of this study is to systematically review the literature for tests commonly used in rugby to measure physical or physiological characteristics and rugby-specific skills, documenting evidence of reliability and validity of the identified tests.

Methods/design: A systematic review will be conducted. Electronic databases such as Scopus, MEDLINE via EBSCOhost and PubMed, Academic Search Premier, CINAHL and Africa-Wide Information via EBSCOhost will be searched for original research articles published in English from January 1, 1995, to December 31, 2015, using a pre-defined search strategy. The principal investigator will select potentially relevant articles from titles and abstracts. To minimise bias, full text of titles and abstracts deemed potentially relevant will be retrieved and reviewed by two independent reviewers based on the inclusion criteria. Data extraction will be conducted by the principal investigator and verified by two independent reviewers. The Consensus-based Standards for the Selection of Health Measurement Instruments (COSMIN) checklist will be used to assess the methodological quality of the selected studies.

Discussion: Choosing an appropriate test to be included in the screening test battery should be based on sound psychometric properties of the test available. This systematic review will provide an overview of the tests commonly used in rugby union and other related high intermittent team sports characterised by skill executions using the hands and legs such as Rugby League and Australian Rules Football. In addition, the review will highlight the psychometric properties of the identified tests. This information is crucial in developing a sport-specific test battery which can be used for talent identification, especially among young adolescent players, and injury prevention programmes.
(Continued on next page)

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(Continued from previous page)

Systematic review registration: PROSPERO CRD42015029747

Keywords: Physical, Physiological characteristics, Rugby, Game-specific skills, Systematic review protocol, Psychometric properties

Background

Rugby union (henceforth referred to as rugby) is a popular sport played in many countries worldwide at both junior and senior levels [1]. It is characterised by multiple high-intensity activities interrupted shortly by low-intensity activities [2–5]. The players engage in physically demanding contests such as tackles, rucks and mauls in order to gain possession of the ball [6]. This requires players to possess a wide range of physical attributes allowing them to be fatigue-resistant and stronger in physical contests [7, 8]. Today, the physiological and skills profiling of players has become an important aspect of the game to determine competent players ready to meet the high-intensity demands of the sport [7].

Although there are position-specific requirements in rugby, recent evidence point towards a blend of roles since all rugby players are expected to compete and maintain possession of the ball [6, 9, 10]. Consequently, success in professional rugby circles and other related intermittent team sports such as Rugby League and Australian Rules Football (AFL) that involve similar demands has been attributed to exhibiting (but not limited to) well-developed physiological characteristics such as endurance, muscular strength, power, agility, speed and flexibility [11–13]. In addition, high levels of game-specific skills such as tackling, kicking, passing, catching and reactive agility have also been indicated to be very important in the sport [2, 10, 14–17]. There is burgeoning research showing that physiological characteristics and game-specific skills discriminate significantly between players of different ranks and abilities [18, 19]. Understanding the physiological qualities and game-specific skills that discriminate between players in rugby will allow coaches and researchers to prepare highly effective training programmes and develop specific tests to examine players' proficiencies [20].

There are many different tests available in the literature to measure physical or physiological variables and game-specific skills in rugby (Table 1). At the top level, rugby players are required to perform high-speed running or sprinting during defending or attacking [2, 3]. Speed enables players to move quickly in order to position themselves in attack and defence [21, 22]. According to time-motion studies, rugby players rarely sprint distances greater than 40 m in a single bout of intense activity [21]. Therefore, speed is commonly measured using the sprinting tests performed between distances of 5 and 50 m, whereas speed endurance is usually assessed using repetitive sprinting tests [8, 23–25].

Agility is another physical characteristic essential in rugby [26, 27]. Players are required to make fast decisions while rapidly accelerating, decelerating and changing direction [21, 22]. Several authors have evaluated the agility of rugby players using a number of different tests including the 'L' run, Illinois agility run test, 505 and the modified 505 test [28, 29]. The pre-planned nature of these tests limit their applicability to real game demands since changes of direction in rugby are often in response to stimuli such as an attacking or defending opponent [25, 27, 30]. It is now commonly accepted that perceptual or neuropsychological factors such as anticipation, intuition, sensory processing and decision-making are all important to agility performance [27, 30]. Today, the reactive agility test (RAT) is widely used in literature to evaluate the change in direction with speed while the players are responding to unpredictable stimuli [27, 30, 31].

Muscular strength and power are also important for success in rugby [3]. Muscular strength has been consistently measured using the back squat for the lower body and the bench press for the upper body, testing either 1 or 3 repetition maximum (RM) [19, 32–34]. Rugby players are required to have high levels of muscular power in order to effectively perform the lifting, pushing and pulling tasks that occur during a match [21, 22]. In addition, muscular power is required for line-out jumping, breaking through tackles and agility when attacking [21, 35]. Muscular power is commonly assessed in the lower body using the vertical jump height test [19, 23, 36].

Rugby players use both aerobic and anaerobic energy systems [37]. Rugby matches last 60–80 min with players covering between 5500 and 9929 m depending on the level of competition, pace of the game and players positions [3, 10, 21]. Given the duration of a rugby match, well-developed aerobic power is important for performance [3]. Numerous studies have measured the aerobic capacity of rugby players by estimating maximal oxygen uptake (VO_{2max}) through the multistage fitness test [21, 38–40]. In addition, there are instances where players are required to perform large amounts of high-speed running in a short period of time. As such, well-developed high-intensity running ability is required in order to compete during these periods. Tests commonly used to assess this include the repeated 12-s sprint shuttle test and Yo-Yo Intermittent recovery test level 1 [19, 23, 32, 41].

Table 1 A summary of selected physiological qualities and game-specific skills needed in rugby and the corresponding test(s)

Construct	Test(s)
1. Physical/motor or physiological qualities	
a. Muscular strength and power	
• Upper body muscular strength	3 repetition maximum bench press [19]; 2-kg medicine ball throw [58]
• Upper body strength endurance	Bench press with repetitions [19]; flexed-arm hang test [36]
• Lower body explosive power	Vertical jump test [19]; standing broad jump [44]; countermovement jump test [26]
• Lower body muscular strength	3 repetition maximum full-body squat [19]
• Abdominal strength	Sit-up test [59]
b. Speed/acceleration	10- and 30-m running test [28]; 10- and 40-m sprint test [23]; 20-m sprint test [18]
c. Agility	Illinois test [34]; *t* test [44]; change of direction speed [26]; zigzag run test [26, 36]
• Reactive agility	Reactive agility test [27]
d. Flexibility	Sit and reach test [5]; adapted sit and reach [36]
e. Aerobic capacity	Yo-Yo intermittent recovery test [19]; 20-m multistage endurance run [59]; multistage fitness test [23]
• Speed endurance	Repetitive sprint test [26]; repeated 20-m sprint test [23]; repeated 12-s sprint shuttle test [23]; speed endurance test (test of Halzadine and McNab) [36]
2. Rugby-specific skills	
a. Ground skills ability	Pick up and place test [34]
b. Passing	4-m passing for accuracy test [59]; 7-m passing for distance ability test [28]
c. Kicking	Kicking ability test [28]; place kicking test; air and ground kicking ability test [36]
d. Catching	Catching ability test while moving [28]; catching and throwing over the crossbar [60, 61]
e. Tackling	One-on-one tackling drill in a 10-m grid proficiency assessed using standardised technical criteria [23]
f. Draw and pass	Single- and dual-task draw and pass assessment test [23]
g. Pattern recall and prediction	Pattern recall and prediction test [23]

Rugby-specific skills are also vital for successful performance, and they have been used to differentiate between elite and non-elite players [15, 42]. The basic skills of passing, kicking, running and catching have been reported to represent the fundamental game skills in rugby that are performed by all players [15, 34]. The tests commonly used for passing include passing for accuracy and distance tests, and the tests for kicking include kicking for distance test and place kicking test using a tee, air and ground kicking ability test [28, 34, 36]. Side-stepping ability is usually tested using the side-step ability test involving carrying the ball in both hands running through obstacles and sidestepping to the left and right [36]. Ground skills test is used to assess ground skills ability while running and involves the player picking up the ball in both hands and running around the marker and placing the ball where it was picked while running [36]. Arguably, tackling is one of the core skills needed in rugby by all players. In several studies, tackling proficiency was assessed subjectively by expert rugby coaches based on a standardised skill criteria rating the skill on a Likert scale ranging from 1 (lowest score) to 5 (optimal score) with the players either playing game-related training activities or competing in competitive matches [15, 18, 23].

Identification of tests commonly used to measure physiological or physical qualities and rugby-specific skills is important for the development of screening test batteries. Test batteries can be used by coaches and researchers to determine players' competency level, especially for the purpose of talent identification, creating a profile of each individual athlete, tracking progress over time and also evaluating the effectiveness of interventions [43–46]. However, choosing an appropriate test to use for practical or research purposes should be based on the test displaying acceptable psychometric properties [47, 48]. This is extremely important in sports science as in medical and health-related fields to know which tests are indeed reliable and valid. To help rugby sport coaches to determine appropriate tests to include in the evaluation of physical characteristics and rugby skills, the evidence for reliability and validity of the tests should be considered [49]. Despite the widespread use of physical or game-specific skills in the literature, studies exploring the psychometric properties of tests commonly used in rugby are limited. To the authors' knowledge, no systematic review has been conducted to review the psychometric properties of the tests commonly used to measure physiological characteristics and game-specific skills in rugby. A recent systematic review conducted by Robertson et al. [47] reviewed 22 studies to determine the psychometric properties of tests for skills from a broad range of sports. Only one study investigating rugby league was included in the review. However, the majority (95 %) of the reviewed studies investigated test-retest reliability (95 %) and content validity (68 %).

Objectives

The purpose of this systematic review is twofold and, hence, will be conducted in two stages.

Stage 1

1. The specific objective is to determine the range of tests, used alone or included in test batteries, commonly used to measure physical or physiological characteristics and game-specific skills needed in rugby union and other high intermittent team sports characterised by skill executions using the hands and legs such as Rugby League and Australian Rules Football (AFL).

Stage 2

1. The specific objective of stage 2 is to document the psychometric properties of the previously identified tests.

Methods

Study design

A systematic review will be conducted. This systematic review forms part of a broader doctoral study with the ultimate aim of developing a screening test battery encompassing validated tests. Once developed, the scores for the test battery will be used to predict the risk of injury in a prospective study among Zimbabwe male adolescent elite rugby players. In Zimbabwe, rugby is a popular sport played competitively by males [50] and this accounts for the specific focus on males. The full doctoral thesis is planned around three phases. In the first phase, a narrative literature review will be conducted first to describe the qualities and skills needed in the game of rugby and identify the commonly used tests for the identified variables. Subsequently, a small-scale qualitative study using interviews will be conducted to explore the perceptions of local rugby coaches on the qualities and skills crucial in rugby and the tests they administer to evaluate the identified factors. This systematic review will form the last part of the first phase and will then be conducted mainly to report on the evidence of the psychometric properties of commonly used tests for game-specific skills and physical or physiological variables. This review will largely be informed by conventional methods of conducting systematic reviews and will be written in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) guidelines by Moher et al. [51] (see Additional file 1).

Study registration

The protocol has been registered on PROSPERO with the registration number CRD42015029747.

Criteria for inclusion of studies

Study design

One of the main principles of a systematic review is to include all available evidence and then summarise narratively or quantitively the findings [52]. Therefore, there will be no restrictions on the type of study to be included in the review.

Sport context

Although rugby union differs subtly from rugby league in rules, scoring and patterns of play, the similarities are not only in game duration, field size, player positions and goal posts but also in the physical demands, physiological responses of players during play and the technical or perceptual skills needed in the sports [53]. Therefore, this systematic review will include articles on all rugby codes (i.e. rugby league) and other related sports such as Rugby League and AFL with similar executions of skills by both hands and legs characterised by multiple high-intensity activities (e.g. high-speed running and sprinting) interrupted intermittently by low-intensity activities.

Outcome measures

Rugby players have to exhibit a blend of physical or physiological and rugby-specific skills to cope with the demands of the game [28]. To be included in this review, studies should report on the following two concepts: (a) physical or physiological characteristics and (b) rugby-specific skills. In addition, studies should provide detailed information on the procedure used to measure any of the aforementioned qualities and the instrument or test used in measuring in their methods section. Explicitly expressed in the text of the studies to be included in this review should be information at least on one psychometric property used to evaluate the test/instrument and the results obtained for the measurement property.

Participants

Rugby is played competitively and professionally from secondary school to senior club level worldwide [28, 54]. Studies to be included in this systematic review should have detailed information about the participants. Studies reported for adolescents considered from above 10 years through to adults will be considered. In this review, studies involving male adults or adolescent rugby union or league players will be included since the identified tests will be used in males who participate in competitive rugby.

To answer the second objective, all the studies included in stage 1 will be evaluated for psychometric properties of the test(s) included in the study. The studies will be included if they state explicitly information on at least one psychometric property tested for the included test(s), even if the primary objective of the study is not on psychometric properties. Articles utilising tests with measurement properties investigated previously elsewhere, provided that the validation involved rugby participants, will also be included since the purpose of this review is to document the evidence of reliability and validity of the test. In addition, articles primarily evaluating the psychometric properties of a test identified in the previous stage as commonly used will also be included provided that the test is designed for and tested among rugby or rugby-related sports participants. However, to be able to assess the methodological quality of these studies, they have to provide detailed information on the procedure of the included test(s) for the mentioned quality or skill.

Exclusion criteria

Studies that do not fulfil any of the inclusion criteria will be excluded. Non-scholarly documents will be excluded; these include thesis, editorials, newspaper articles and lecture notes as suggested in the literature [48]. In addition, studies not published in English will be excluded as the authors are predominantly from English-speaking countries and the review has no funding to fund the back and forth translation of non-English articles. No restriction criteria will be applied for country. Articles describing tests for physical or physiological qualities and game-specific skills on rugby participants living with disabilities such as quadriplegics will be excluded as the technical and physiological skills needed could be different.

Search methods for identification of studies

A computerised, systematic literature search will be conducted in electronic databases such as Scopus, MEDLINE via EBSCOhost and PubMed, Academic Search Premier, CINAHL (Cumulative Index to Nursing and Allied Health Literature) and Africa-Wide Information via EBSCOhost. In accordance with recommendations for systematic reviews on measurement properties [55], a hand search will be done on the reference lists of included articles to identify additional relevant studies. In addition, the Science Citation Index for citation searching will also be used to search for articles. There has been an exponential increase in the volume of scientific research on rugby after the sport attained professional status in 1995 [6]. Hence, this review will include articles published in the last 20 years between January 1, 1995, and December 31, 2015.

Search strategy

Studies on psychometric properties of measurement instruments have been reported to be difficult to find in literature especially on PubMed [48]. This has been attributed to indexing problems, large variation in terminology used for measurement properties and the poor reporting of measurement properties in abstracts [48]. Therefore, a search strategy proposed by Terwee et al. [48] will be used as a guide to the selection of the key or index terms to be used when searching for articles. The search strategy was developed in consultation with an expert librarian (GM) in systematic review from the University of Cape Town. Additional file 2 shows the search strategy to be used in PubMed and will consist of a combination of the following search themes connected with the Boolean term AND:

i. Construct-related search terms, for example, physical OR physiological OR rugby skill*
ii. Population-related search terms, for example, adult OR senior OR adolescen* OR youth
iii. Sport-related search terms, for example, rugby OR rugby union OR rugby league
The above search strategy will constitute stage 1 and will be used to provide an overview of the tests commonly used in the literature to measure physiological variables and game-specific skills. The search strategy below will be used in stage 2 to determine the psychometric properties of the identified tests. Including the 'sport-related' search terms used in stage 1, the search strategy for stage 2 will additionally include 'instrument-related search terms' and 'measurement properties-related search terms'. The search strategy consisted of a combination of the following search themes connected with the Boolean terms AND:
iv. Instrument-related terms, for example, vertical jump test* OR multistage fitness test* OR repeated ability sprint test*
v. Measurement properties-related terms, for example, psychometr* OR clinimetr* OR clinometr* OR reproducib* OR reliab*

For 'instrument-related' search terms, the specific names of the tests identified in the first stage of the review will be entered to search for their psychometric properties.

Selection process

The selection process will then be conducted as recommended by van Tulder et al. [52] and Reimers et al. [55]. The principal investigator will apply the inclusion criteria to select potentially relevant articles from titles and abstracts. Before the screening phase, all the search results will be merged in Rev Manager Version 5.3 to identify and remove duplicates. The full text of titles and abstracts deemed potentially relevant will be retrieved, and two independent reviewers (GF and EB) will review the full-text articles for inclusion using predefined eligibility criteria. Any disagreements that arise will be resolved through discussion or referral to a third party (BE).

Data management

Eligible articles gathered for the systematic review will be downloaded and stored in a Dropbox folder accessible to all the authors. An account will be created by the principal investigator (MC) in the respective databases used to retrieve articles. Hence, the online version of the articles and the electronic search strategy used for each database will be saved therein.

Data extraction

After identification and complete analysis of the full-text articles for eligibility, the primary author will extract data from each article into a Microsoft Excel data collection form. For the first objective, the following data will be captured: the publication details (first author, year of publication), the name(s) of the physiological or physical characteristic or game-specific skill examined in the study and the corresponding test(s) used to measure the variables. The frequency of use of each test in all the included studies will also be reported. To be able to describe the characteristics of the studies included in the review, additional information on sport context, age of participants, country and target population will also be extracted. Thereafter, the extracted data will be assessed by two reviewers (SO and JMD) for accuracy against the original sources.

For the second objective on psychometric properties, the following data will also be captured: the publication details (first author, title, year of publication), study and subject characteristics, sport context, name of the test (s) used, a short description of its procedure, psychometric properties reported (reliability, internal consistency, measurement error/smallest detectable difference, content validity, construct validity, responsiveness) and the results obtained. Two independent assessors (JMD and SO) will verify the extracted data for accuracy and consistency against the original articles.

Outcomes and prioritisation

For this review, the primary outcome measures are tests used in rugby and related sports commonly to measure physical or physiological characteristics and rugby-specific skills. Secondarily, evidence of measurement properties such as reliability and validity will be captured for each identified test for the qualities and skills needed in the sport of rugby.

Methodological quality assessment

Methodological quality assessment of included studies is a necessary part of systematic review [56]. In order to assess the overall quality of the selected articles, the 'Consensus-based Standards for the Selection of Health Measurement Instruments' (COSMIN) checklist will be used as a guide. The checklist is a standardised tool for evaluating the rigour of psychometric studies of measurement instruments, and only the methodological part of the checklist will be used [54, 55]. It evaluates nine psychometric properties of internal consistency, reliability, measurement error, content validity, construct validity (i.e. structural validity, hypothesis testing, and cross-cultural validity), criterion validity, responsiveness, interpretability and generalisability (Table 2) [56, 57].

Two authors (EB and GF) will be used to assess the quality and calculate the score of the included articles. Disagreements between reviewers will be resolved by discussion or the use of a third person (BE). The scoring system is designed that items are scored as 'excellent' when there is evidence of adequate methodological quality,'good' when relevant information is not fully reported but adequate quality can be assumed, 'fair' if the methodological quality is in doubt and 'poor' when there is evidence that the methodological quality is not adequate [55]. Each psychometric property will be evaluated separately by taking the lowest rating of any item based on the 4-point scale from excellent, good, fair and poor [56].

Quality criteria for measurement properties

The Quality Criteria for Measurement Properties (Table 2) as given by Terwee et al. [57] will be used to rate each psychometric property in the articles as positive, negative or questionable depending on the results of the property reported. Test-retest reliability or interrater reliability will be considered substantial for intraclass correlation coefficients (ICC) above 0.70 [57]. In addition, tests will be considered to have acceptable construct validity if the effect size (ES) between groups is as follows: <0.2 trivial, 0.2–0.5 small, 0.5–0.8 medium and >0.8 large [2]. In the case of the effect size not reported in any of the included articles, the authors of the respective studies will be contacted directly for a maximum of three times through email to either provide the information necessary for its calculation or provide the actual effect size. If no response is received from the authors after the third attempt, provided all the parameters are available, the effect size will be calculated by the primary investigator and will be reported as 'calculated'.

Data synthesis

A narrative synthesis of the findings from the included studies will be provided due to the likely heterogeneity of the studies. A pilot testing of the search strategy for

Table 2 Quality of the statistical outcomes to determine psychometric properties [57, 62]

Measurement property	Definition	(Rating) quality criteria[a,b]
Reliability		
Internal consistency	The extent to which items in a (sub)scale are intercorrelated, thus measuring the same construct	(+) Factor analyses performed on adequate sample size (7 * # items and >100) AND Cronbach's alpha(s) calculated per dimension AND Cronbach's alpha(s) between 0.70 and 0.95 (?) No factor analysis OR doubtful design or method (−) Cronbach's alpha(s) 0.70 or O 0.95, despite adequate design and method (0) No information found on internal consistency
Reproducibility		
Agreement	The extent to which the scores on repeated measures are close to each other (absolute measurement error)	(+) MIC < SDC OR MIC outside the LOA OR convincing arguments that agreement is acceptable (?) Doubtful design or method OR (MIC not defined AND no convincing arguments that agreement is acceptable) (−) MIC > SDC OR MIC equals or inside LOA, despite adequate design and method; (0) No information found on agreement
Reliability	The extent to which patients can be distinguished from each other, despite measurement errors (relative measurement error)	(+) ICC > 0.70 OR *k* > 0.70 (?) Doubtful design or method (e.g. time interval not mentioned) (−) ICC or weighted Kappa ≤0.70, despite adequate design and method (0) No information on reliability found
Validity		
Content validity	The extent to which the domain of interest is comprehensively sampled by the items in the questionnaire	(+) A clear description is provided of the measurement aim, the target population, the concepts that are being measured, and the item selection AND target population and (investigators OR experts) were involved in the item selection (?) A clear description of the above-mentioned aspects is lacking OR only target population involved OR doubtful design or method (−) No target population involvement (0) No information found on target population involvement
Construct validity	The extent to which scores on a particular questionnaire relate to other measures in a manner that is consistent with theoretically derived hypotheses concerning the concepts that are being measured	(+) Specific hypotheses were formulated AND at least 75 % of the results are in accordance with these hypotheses (?) Doubtful design or method (e.g. no hypotheses) (−) Less than 75 % of hypotheses were confirmed, despite adequate design and methods (0) No information found on construct validity
Criterion validity (predictive or concurrent	The extent to which scores on a particular questionnaire relate to a gold standard	(+) Correlation with standard ≥0.70 OR no statistically significant differences between the two tests found OR sensitivity and specificity ≥0.70 OR convincing arguments that gold standard is 'gold' AND correlation with gold standard >0.70[c] (?) No convincing arguments that gold standard is 'gold' OR doubtful design or method (−) Correlation with standard <0.70 or AUC < 0.70 OR statistically significant differences between outcome measures and gold standard OR sensitivity or specificity <0.70
Responsiveness	The ability of a questionnaire to detect clinically important changes over time	(+) SDC or SDC < MIC OR MIC outside the LOA OR RR O 1.96 OR AUC > 0.70 (?) Doubtful design or method (−) SDC or SDC > MIC OR MIC equals or inside LOA OR RR < 1.96 OR AUC < 0.70, despite adequate design and methods (0) No information found on responsiveness
Floor and ceiling effects	The number of respondents who achieved the lowest or highest possible score	(+) ≤15 % of the respondents achieved the highest or lowest possible score (?) Doubtful design or method (−) >15 % achieved the highest and lowest possible score despite adequate designs and methods (0) No information found on interpretation

Table 2 Quality of the statistical outcomes to determine psychometric properties [57, 62] *(Continued)*

Interpretability	The degree to which one can assign qualitative meaning to quantitative scores	(+) Mean and SD scores presented of at least 4 relevant subgroups of patients and MIC defined (?) Doubtful design or method OR less than 4 subgroups OR no MIC defined (0) No information found on interpretation

MIC minimal important change, *SDC* smallest detectable change, *LOA* limits of agreement, *ICC* intraclass correlation, *SD* standard deviation
[a](+) positive rating; (?) indeterminate rating; (–) negative rating; (0) no information available
[b]Doubtful design or method = lack of a clear description of the design or methods of the study, sample size smaller than 50 subjects (should be at least 50 in every (subgroup) analysis), or any important methodological weakness in the design or execution of the study
[c]Adopted from van Bloemendaal et al. [26]

both stages of this review showed a number of different studies. In that case, a narrative synthesis may be necessary to provide potential explanations for contrasting findings observed in the literature, summarising the information in tables and explaining in text the characteristics and findings of the included studies for both stages of the review.

Risk of bias in individual studies

The COSMIN checklist will be used for assessing the methodological quality of all the studies to be included in the review. The use of the COSMIN to this effect precludes the possibility of selecting and evaluating individual studies reporting on tests that were developed using designs with poor methodological rigour.

Discussion

The purpose of this systematic review is to identify tests for physical or physiological and game-specific skills that are psychometrically sound and that can be amalgamated in a test battery for use in rugby. Identification of tests commonly used to measure these characteristics is important for the development of multidimensional test batteries integrating all essential qualities needed in rugby. The test batteries will enable the recognition and development of talented rugby players at an early age.

Additional files

Additional file 1: PRISMA-P guidelines for systematic review protocols. (DOCX 13.8 kb)

Additional file 2: Search strategy. (DOCX 13.9 kb)

Abbreviations

AFL, Australian Rules Football; AUC, area under the curve; CINAHL, Cumulative Index to Nursing and Allied Health Literature; COSMIN, Consensus-based Standards for the Selection of Health Measurement Instruments; ES, effect size; ICC, intraclass correlation coefficient; LOA, limits of agreement; MIC, minimal important change; PRISMA-P, Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol; SD, standard deviation; SDC, smallest detectable change

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Authors' contributions

MC and BE conceptualised the idea of writing the systematic review protocol. MC prepared the manuscript. GF and BE read the manuscript and provided insightful comments on the design of the review protocol in a supervisory role. All authors read and approved the protocol for publication.

Authors' information

MC is a registered PhD student at the University of Cape Town. BE is the overall supervisor of the doctoral thesis. GF is a senior physiotherapy lecturer at the University of Cape Town and acting in the capacity of a co-supervisor.

Competing interests

The authors declare that they have no competing interests.

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Appendix I: Stage 1 search strategy

((speed OR sprint OR acceleration OR momentum OR linear speed OR velocity OR repeated sprinting OR sprinting force OR repeated sprinting abilit* OR speed endurance OR running OR running speed OR prolonged high intensity intermittent running ability OR high intensity running OR aerobic power OR aerobic capacity OR maximal aerobic power OR anaerobic endurance OR anaerobic endurance fitness OR change of direction OR change of direction speed OR ability OR power OR muscular power OR explosive power OR strength OR muscular strength OR lower body muscular strength OR upper body muscular strength OR lower body muscular power OR upper body muscular power OR muscular endurance OR upper body muscular endurance OR flexibility))*

AND

((adult OR senior OR adolescent OR youth OR teenager* OR elite OR sub-elite OR male* OR under 13 players OR U13 OR under 14 players OR U14 OR under 15 players OR U15 OR under 16 players OR U16 OR under 17 players OR U17 OR under 18 players OR U18 OR under 19 players OR U19 OR under 20 players OR U20 OR first grade OR second grade OR age category OR age group OR professional OR semi-professional OR amateur OR boy OR junior OR athletes OR forwards OR backs OR positional differences OR playing position))*

AND

((rugby OR rugby union OR rugby union team OR rugby league OR rugby player OR elite OR sub-elite OR rugby players OR collision sport* OR talented OR talent identification OR talent selection OR player assessment OR player development OR non-talented OR draft* OR non-draft* OR skilled players OR non-skilled players OR starters OR non-starters OR positional differences OR collision sport OR intermittent sport OR contact sport))*

AND

((physical OR physical skill OR physical characteristic* OR physical fitness OR physical qualities OR physical demands OR physical abilities OR motor skill* OR motor abilities OR motor component OR motor performance OR movement characteristic* OR performance analys* OR performance OR performance standards OR physiological OR physiological characteristic* OR physiological variable* OR physiological capacities OR physiological demands OR physiological testing OR fitness measures OR fitness profile OR fitness test))*

Appendix J: General characteristics of included studies for stage 1

Author	Sample size	[1]Age (years)	Target Population	Study design	Country	Sport	Physiological construct
Appleby et al (2012)[80]	20	24.4 ± 3.4-26.4±3.4	Adults	Longitudinal	Australia	Rugby union	Strength
Argus et al (2012)[13]	112	16.6 ± 0.8-24.4 ± 2.7	Adolescents & Adults	Cross-sectional	New Zealand	Rugby union	Strength, power
Atkins (2006)[103]	50	21.1± 4.7-22.1± 5.0	Adults	Cross-sectional	England	Rugby league	[a]HIRA
Austin et al (2013)[24]	36	24.4 ± 3-24 ± 4	Adults	Test re-test	Australia	Rugby league & union	[b]HIEP
Baker (2009)[81]	64	19.5 ± 1.7-25.0 ±3.3	Adults	Cross-sectional	Australia	Rugby league	Strength-endurance
Baker and Newton (2008)[77]	40	22.6 ± 3.6-25.3 ± 3.4	Adults	Cross-sectional	Australia	Rugby league	Strength, power, agility, speed.
Baker (2002)[78]	95	16.2±1.2-23.5±3.2	Adolescents & Adults	Cross-sectional	Australia	Rugby league	Strength, power
Bradley et al (2015)[5]	45	21-33	Adults	Longitudinal (repeated measures)	England	Rugby union	Speed, strength
Comfort et al (2011)[75]	18	21.7 ± 4.1	Adults	Cross-sectional	England	Rugby league	Speed, agility, power, strength
Cobley et al (2014)[47]	1 172	U13-U15 players	Adolescents	Longitudinal	United Kingdom	Rugby league	Muscular power, speed, change of direction speed, maximal aerobic power
Darrall-Jones et al (2015)[53]	67	15.5 ± 0.3-19.0 ± 1.1	Adolescents	Cross-sectional	England	Rugby union	Speed, agility, power, [a]HIRA
Darrall-Jones et al (2015b)[59]	67	15.4±0.3-19.3±1.2	Adolescents	Cross-sectional	England	Rugby union	Speed, [a]HIRA, maximal aerobic speed
De Lacey et al (2014)[104]	39	24 ± 3	Adults	Cross-sectional	New Zealand	Rugby league	Speed, strength, power
Delaney et al (2015)[72]	31	24.3±4.4	Adults	Cross-sectional	Australia	Rugby league	Speed, change of direction ability, strength, power

Durandt et al (2014)[27]	174	U16-U18 players	Adolescents	Cross-sectional	South-Africa	Rugby union	Speed, agility, strength, endurance, aerobic fitness
Gabbett (2000)[61]	35	26.5 ± 5.1	Adults	Cross-sectional	Australia	Rugby league	Speed, power, maximal aerobic power
Gabbett (2002a)[30]	159	12.3-25.1	Adolescents & Adults	Cross-sectional	Australia	Rugby league	Power, speed, agility, estimated $V0_{2MAX}$
Gabbett (2005a)[31]	240	16-18	Adolescents	Cross-sectional	Australia	Rugby league	Power, speed, agility, maximal aerobic power
Gabbett (2005b)[32]	45	-	Adolescents	Cross-sectional	Australia	Rugby League	Power, speed, agility, maximal aerobic power
Gabbett (2005c)[33]	68	≥ 18	Adults	Cross-sectional	Australia	Rugby league	Power, speed, agility, maximal aerobic power
Gabbett (2006)[34]	415	21.1 ± 3.4-25.7 ± 5.6	Adults	Cross-sectional	Australia	Rugby league	Power, speed, agility, maximal aerobic power
Gabbett et al (2007)[35]	86	22.5±4.9	Adults	Cross-sectional	Australia	Rugby league	Power, speed, agility, maximal aerobic power
Gabbett et al (2008a)[19]	42	23.6 ± 5.3	Adults	Cross-sectional	Australia	Rugby league	Speed, change of direction speed
Gabbett et al (2008b)[36]	35	14.1 ± 0.2-16.9 ± 0.3	Adolescents	Longitudinal (repeated measures)	Australia	Rugby league	Speed, power, muscular endurance, agility, maximum aerobic power
Gabbett (2009)[73]	12	24.4 ± 3.5	Adults	Cross-sectional	Australia	Rugby league	Acceleration, power, change of direction speed
Gabbett (2009b)[37]	88	13.2 ± 0.6-16.5 ± 0.3	Adolescents	Cross-sectional	Australia	Rugby league	Speed, change of direction speed, power, maximal

							aerobic power
Gabbett et al (2011a)[16]	58	23.8 ± 3.8	Adults	Cross-sectional	Australia	Rugby league	Speed, repeated sprint ability, change of direction speed, power, prolonged HIRA
Gabbett et al (2011b)[49]	86	23.3±3.8	Adults	Cross-sectional	Australia	Rugby league	Speed, change of direction, power, repeated sprint ability, prolonged HIRA, maximal aerobic power
Gabbett et al (2013)[50]	38	23.1 ± 2.7	Adults	Prospective cohort experimental design	Australia	Rugby league	Repeated sprint ability, prolonged HIRA, maximal aerobic power.
Gabbett et al (2009c)[65]	64	15.9±0.6-16.0±0.2	Adolescents	Cross-sectional	Australia	Rugby league	Speed, change of direction speed, muscular power, maximal aerobic power
Gabbett & Seibold (2013)[15]	32	24± 3	Adults	Prospective cohort design	Australia	Rugby league	Strength, strength endurance, power, prolonged HIRA
Galvin et al (2013)[29]	30	18.4 ± 1.5	Adolescents	Single-blind placebo controlled design	England	Rugby league & union	Repeated sprint training, speed, prolonged HIRA
Green et al (2011)[6]	28	19 ± 1.3-19 ± 1.7	Adolescents	Cross-sectional	Ireland	Rugby union	Speed, change of direction ability
Hansen et al (2011)[79]	40	23.7 ± 5.0	Adults	Cross-sectional	Australia	Rugby union	Speed, power
Holloway et al (2008)[70]	12	21.5 ± 2.2	Adults	Cross-sectional	Australia	Rugby league	Anaerobic endurance

Jarvis et al (2009)[10]	19	23.0 ± 5.4	Adults	Cross-sectional	Wales	Rugby union	Speed, agility, maximum aerobic power
Johnston & Gabbett (2011)[51]	12	22.7 ± 2.2	Adults	Randomized, counterbalanced cross over experimental	Scotland	Rugby league	Repeated sprint ability & effort
Johnston et al (2015)[54]	31	16.5 ± 0.5	Adolescents	Between groups, repeated measures experimental design	Australia	Rugby league	HIRA
Johnston et al (2015b)[60]	21	19.2±0.7	Adolescents	Cross-sectional	Australia	Rugby league	HIRA, muscular strength, power
Kirkpatrick and Comfort (2013)[38]	24	18.7 ± 0.9	Adolescents	Cross-sectional	England	Rugby league	Power, strength, speed
Krause et al (2015)[76]	485	U12-U15	Adolescent	Cross-sectional	Australia	Rugby union	Speed, power
Lombard et al (2015)[7]	453	18.1 ± 0.7	Adolescents	Repeated cross-sectional design	South Africa	Rugby union	Strength, endurance, speed
Moore and Murphy (2003)[71]	15	22.5 ± 2.5	Adults	Cross-sectional	Australia	Rugby union	Anaerobic capacity
Meir et al (2001)[58]	146	N/m	Adults	Cross-sectional	England and Australia	Rugby league	Speed, Muscle strength, power, endurance, agility
Parsonage et al (2014)[39]	156	15±7	Adolescents	Cross-sectional	UK	Rugby union	Power, speed, endurance capacity
Pienaar and Coetzee (2013)[28]	40	18.9 ± 0.4	Adolescents	Pre-posttest, randomized experimental design	South Africa	Rugby union	Power, acceleration, speed, agility, anaerobic capacity
Scott et al (2015)[68]	55	15.6 ± 0.3-19.4 ± 0.5	Adolescents	Test retest, comparative cross-sectional	Australia	Rugby league	Prolonged HIRA
Serpell et al (2010)[74]	30	≥ 18	Adolescents & Adults	Within subject & between subject experimental	Australia	Rugby league	Agility

				design			
Smart and Gill (2013)[42]	44	15.3±1.3	Adolescents	Pre-post experimental control design	New Zealand	Rugby union	Strength, power, speed, anaerobic and aerobic running
Smart et al (2013)[52]	1 161	*N/m	Adults	Retrospective, secondary data analysis	New Zealand	Rugby union	Strength, power, speed, repeated sprint ability.
Smart et al (2014)[17]	510	*N/m	Adults	Retrospective, secondary data analyses	New Zealand	Rugby union	Strength, speed, power, repeated sprint ability
Till et al (2016)[18]	81	U17-U19	Adolescents & Adults	Cross-sectional, Longitudinal	United Kingdom	Rugby League	Speed, Muscular power, strength Endurance,
Till et al (2014a)[69]	133	15.5-20.1	Adolescents	Longitudinal	England	Rugby league	Power, speed, endurance, strength
Till et al (2014b)[55]	75	13.0-19.9	Adolescents	Longitudinal	England	Rugby league	Power, speed, endurance, strength.
Till et al (2015)[56]	130	U16-U20	Adolescents	Longitudinal	England	Rugby league	Power, speed, endurance, strength
Till and Jones (2015)[57]	121	12.8-15.5	Adolescents	Longitudinal	England	Rugby league	Power, speed, endurance
Till et al (2011)[43]	1 172	13.57±0.27-15.57±0.27	Adolescents	Longitudinal	United Kingdom	Rugby league	Muscular power, Speed, change of direction speed, maximal aerobic uptake
Till et al (2013)[44]	81	13.6±0.2	Adolescents	Longitudinal	United Kingdom	Rugby League	Muscular power, speed, change of direction, maximal aerobic power
Till et al (2014c)[45]	81	13.62±0.24	Adolescents	Longitudinal	United Kingdom	Rugby League	Muscular power, speed, change of direction speed,

							maximal aerobic power
Till et al (2016b)[41]	580	U13-U15	Adolescents	Longitudinal	United Kingdom	Rugby League	Speed, Change of direction speed, Muscular power, maximal aerobic power
Till et al (2013b)[46]	1 172	U13-U15	Adolescents	Longitudinal	United Kingdom	Rugby League	Speed, muscular power, change of direction speed, maximal aerobic power
Till et al (2016c)[66]	257	U15	Adolescents	Longitudinal	United Kingdom	Rugby league	Muscular power, speed, change of direction speed, maximal aerobic power
Till et al (2015b)[67]	580	13.60±0.55-13.80±0.72	Adolescents	Cross-sectional	United Kingdom	Rugby League	Speed, change of direction speed, muscular power, maximal oxygen uptake.
Till et al (2010)[48]	683	13.6±0.27-15.54±0.27	Adolescents	Longitudinal	United Kingdom	Rugby league	Speed, change of direction speed, muscular power, maximal oxygen uptake.
Vaz et al (2014)[12]	46	26.2 ± 2.8-26.7 ± 2.9	Adults	Cross-sectional	Portugal	Rugby union	Strength, speed, maximal aerobic power
Waldron et al (2014a)[62]	28	15.1±0.4-17.0±0.4	Adolescents	Longitudinal	Australia	Rugby league	Speed, power, aerobic endurance
Waldron et al (2014b)[63]	13	15.1±0.3-17.0±0.3	Adolescents	Longitudinal	Australia	Rugby league	Speed, power, aerobic endurance
Gabbett (2002b)[64]	66	24±4	Adults	Cross-sectional	Australia	Rugby league	Power, speed, agility, maximal aerobic power

Gabbett (2006b)[40]	77	16.7-27.3	Adolescents & Adults	Cross-sectional	Australia	Rugby league	Speed, agility, maximal aerobic power

HIEP=high intensity exercise performance; HIRA=high-intensity intermittent running ability ʅ age was reported as mean±standard deviation or range (for one sample of participants) or group range (if a study had more than two groups of participants); N/m-not mentioned; strength denotes lower or upper body muscular strength; power denotes lower or upper body muscular power.

Appendix K: Procedures for the tests identified in the included studies

Physiological construct(s)	Tests identified	Basic description on how the tests were performed in included studies	Outcome measures	References
Speed	5m, 10m, 15m, 20m, 30, 40m, 50m and 60m sprint tests	Players run along the 60m distance from a pre-determined starting point. Running speed evaluated at 5m, 10m, 20m, 30m, 40m, 50m and 60m using dual beam electronic timing gates.	Total sprint time per each distance (s)	[5-8, 10,16-19, 27, 29-49, 52, 53, 55-67, 69, 73, 75-77, 79]
Repeated sprinting ability (RSA)	Repeated 20m sprint tests	Players perform 10 or 12 maximal effort sprints over a 20m distance with each sprint performed on a 20 or 30-second cycle. Recovery characterised by walking around the cone 10m from the end of the sprint track.	Total repeated sprint time (s), percentage decrement, average heart rate (b.min^{-1}), peak heart rate (b.min^{-1}), rating of perceived exertion.	[16, 29, 49-51]
	Rugby-specific repeated speed (RS^2) test	The test consists of three sets of three or four individual sprints performed maximally at set time intervals. Each set of sprints is separated by periods of standardised work where the players jog with a weighted bag. Players repeated sprints are measured using electronic timing gates over the same distance as speed (30m for backs and 20m for forwards and half backs).	Mean time per sprint (s), *fatigue, mean of 12 sprints for 20m for forwards and the mean of 9 sprints for 30m for backs	[17, 52]
Repeated effort ability (REA)	Repeated-effort test	The protocol comprises of 12×20m sprints and tackles with each sprint commencing every 20seconds and the tackle performed after each 20m sprint.	Total repeated effort time(s), % decrement, average heart rate (b.min^{-1}), peak heart rate (b.min^{-1}), rating of perceived exertion	[51]
Repeated high intensity exercise performance (RHIE)	RHIE Backs test	Each player complete 3×20m sprints on a 20s cycle. After 3 sprints, players complete 2 tackles 10m away with 20s recovery. This drill is repeated three times for each participant.	Individual sprint time (s), sum of sprint time (s), decrement in sprint time over the 3 sets of sprints (s)	[24]
	RHIE RL Forward test	Similar to the RHIE Backs test, except that players complete 5	Sum of sprint times	[24]

		tackles in each circuit.	(s), decrement in sprint time (s)	
	RHIE RU Forward test	Each player complete 3×20m sprints on a 20s cycle. After 3 sprints, players complete a 'scrum sled shuttle' four times. Then players repeat the sprint shuttles (3×20m). After that, players tackle a tackle bag at 10m four times	Total sprint time (s), decrement in sprint performance (s)	[24]
Prolonged high intensity intermittent running ability/Endurance	Yo-Yo intermittent recovery test (level 1)	Players perform 2×20m runs back and forth at a progressively increasing speed keeping to a series of beeps/audio signals from compact disc. Players perform the test at level 1.	Total distance covered (m), last level reached	[15, 19, 53-56, 59, 60]
	Yo-Yo intermittent recovery test (level 2)	Same as above but the test is performed at level 2.	Total distance covered (m)	[24]
	Repeated 12s sprint shuttle speed test	Players perform 8×12s maximal effort shuttles (sprinting forward 20m, turning 180 degrees and sprinting 20m), each shuttle performed at 48s cycle.	Total sprint distance, percentage decrement	[16, 49, 50]
	Multistage fitness test	Players run back and forth along a 20m track keeping in time with the series of beeps on a compact disc with the speed progressively increased until volitional exhaustion.	Total distance covered (m)	[57]
	5 minute run	Players are required to cover as much distance as possible around the course in a 5-minute period.	Total distance covered (m)	[58]
Maximal aerobic fitness	Multistage(shuttle run) fitness test	Same as above	Number of shuttles/laps/levels completed, total distance covered (m), predicted VO_{2MAX}	[7,8, 10, 16, 27, 30-37, 40, 41, 43-46, 48-50, 61-67]
	Yo-yo intermittent recovery test (level 1)	Players perform 20m runs back and forth at a progressively increasing speed keeping to a series of beeps/audio signals from compact disc. Players perform the test at level 1.	VO_{2MAX} predicted via the equation: distance run (m)×0.0084 +36.4	[69]
	30-15 Intermittent Fitness test ($30\text{-}15_{IFT}$)	30s shuttle runs interspersed with 15s periods of passive recovery. Players run back and forth between 2 lines 40m apart at a pace governed by a pre-recorded beep.	Last stage reached, running velocity (V_{IFT})	[68]

	1 500m run (Metabolic Fitness Index for Team Sports)	Players would perform the 1 500m run on a synthetic running track.	Time taken to complete the distance (m)	[42]
Maximal aerobic speed/Anaerobic speed reserve	30-15 Intermittent Fitness test (30-15_{IFT})	30s shuttle runs interspersed with 15s periods of passive recovery. Players run back and forth between 2 lines 40m apart at a pace governed by a pre-recorded beep.	Maximal aerobic speed (MAS), Anaerobic speed reserve (ASR)	[53, 59]
Anaerobic endurance	Triple 120m shuttle (T120S) test	Players perform 3 sets of 120m shuttle sequences.	Time taken to complete the 120m shuttle, maximum heart rate, blood lactate, rating of perceived exertion	[70]
	Wingate 60 (w60) cycle test	Each player will perform a 60s all out maximal effort on a cycle ergometer according to the Wingate protocol.	Maximal heart rate, blood lactate, rating of perceived exertion	[70]
	300m shuttle run test	Players sprint maximally between two lines, 15 times, for a total distance of 300m.	Total time to complete the run (s)	[51]
	400m sprint test (Metabolic Fitness Index for Team Sports)	Players run maximally an entire lap of the track for 400m.	Time to complete the run (s)	[42]
Agility/change of direction speed (CODS)	505 test	Players assume a starting position 10m from timing gates. They accelerate as quickly as possible along the 15-m distance, pivot on the 5m line or turn 180 degrees at the 15m mark and return as quickly as possible through the timing gates placed 5m from a designated turning point	Total time taken (s)	[16, 19, 36, 37, 41, 43-49, 53, 65-67, 72]
	L-run	Three cones placed 5m apart in an 'L' shape. Players run as quickly as possible along the 5m, turn left, run forward 5m, turn 180 degrees and follow same course to finish and dual beam electronic timing gates used to record time.	Total time taken (s)	[19, 31, 32, 34, 35, 40, 58]
	Illinois Agility test	Players start lying in prone on the starting line. On a signal the	Total time taken to	[27, 30, 64]

		players stand up and accelerate towards and around the cones set up. They can sprint for 9m return to the starting line; they swerve in and out of the four cones completing two 9m sprints to finish the agility course.	complete the course (s)	
	Modified 505 test	Two timing gates placed 5m apart from a designated turning point; unlike the traditional 505 test where players start at 10m from the timing gates and therefore 15m from the turning point, players start 5m from the timing gates, pivot on the 5m line and return as quickly as possible through the timing gates	Total time taken to complete the course (s)	[19, 73]
	Change of direction speed test	Players sprint forward 5m then perform a 45 degree change of direction manoeuvre to pass through either left or right finish gate.	Total time taken to complete the course (s)	[6, 74]
	Agility test	Players sprint 5m through the first timing gates to the second timing gates and sprint back to the third timing gate positioned at the starting line 5m from the first and sprint back to the fourth timing gate positioned 5m away from the second time to finish the course	Total time taken to complete the course (s)	[75]
	Novel agility test (no specific name given)	Players sprint 1m at a 45 degree angle, turn around a marker cone, sprint at 45 degrees for 10m back to starting line. Here they make 135 degree turn around another cone and sprint 20m in a straight line perpendicular to the goal line	Total time taken to complete the course (s)	[77]
Lower body muscular power	Vertical jump test	Using a Yardstick device or a board, players stand with feet flat on the ground, fully extended arms and hands, and mark the standing reach height. After assuming a crouch position, players spring upward and touch the yardstick device or the board at the highest possible point.	Vertical jump height calculated as the distance from the highest point reached during and the highest reaching during the vertical jump	[15, 16, 30-36, 40, 42, 49, 61, 64, 65, 73]
	Countermovement jump test (CMJ)	Players put hands on hips and jump from the jump mat or portable force plate from a standing position moving from a self-selected depth in squatting and jump explosively as far as possible. A Takei vertical jump metre may be used.	Jump height, peak power, vertical power was estimated by equation: CMJ power (W) =61.9×Jump height	[18, 38, 39, 41, 43-48, 53, 55-57, 60, 62, 63, 66, 67, 69, 75, 76]

			+36.0 ×body mass-1822.	
	Jump squat test	Players self-select foot position and lower the Olympic bar 40kg to a self-selected depth and then the players are required to jump as explosively as possible. The bar will be resting on upper trapezius. Loaded jump squat may have a resistance of 20kg to 100kgs conducted using the Plyometric system (PPS) or 40kg jump squat from a force plate	Mechanical power output	[13, 75, 77-79]
Lower body muscular strength	One repetition maximum back squat (1RM BS)	Using an Olympic bar and free weights, players back squat until the top of the thigh is parallel with the ground and return to a standing position to record one repetition maximum.	Maximum weight lifted (kgs)	[5, 17, 18, 38, 55, 56, 69, 77, 80]
	Isometric squat on force plate	Players stand on a force plate with the bar of a Smith Machine resting on upper trapezius at a height which results in an angle of 135 degrees knee flexion.	Peak force generated (n)	[75]
	1 RM box squat	Players use a self-selected foot position and lower themselves to sitting position briefly on the box and then return to standing position	One repetition maximum (kgs)	[13, 42]
	3RM full squat exercise	Players perform this with the free weight Olympic-style barbell. Players lower their body until thighs are past parallel with the floor and fully extend the hip and knee joints	Maximum weight lifted (kgs)	[15]
Upper body muscular strength	One repetition maximum bench press (1RM BP)	Players in supine, feet flat on floor, hips and shoulders in contact with the bench, lower the bar to touch the chest and push the bar until the elbows are locked out.	Maximum weight lifted (kg)	[5, 7, 17, 27, 38, 42, 55, 56, 58, 69, 78, 80]
	3RM bench press	The test is performed as above at three repetition maximum	Maximum weight lifted (kg)	[15, 60]
	1RM chin up test	Players use a reverse underhand grip (palms facing towards face). Players instructed to start from a stationary position with arms fully extended and complete a repetition with the chin moving over the bar	One repetition maximum (kgs)	[17, 42]
	Push-Up test	Players begin in prone, with hands on the floor, thumbs shoulder width apart and elbows fully extended. Players are instructed to descend to the tester fist placed on the floor below the players’	The number of push-ups in one minute (n)	[27]

		sternum and then ascend until the elbows are straight.		
	1RM Prone row	Participants lay face down on a bench with the bench height determined by the players reach when the arms are fully extended. Participants have to pull the barbell towards the bench and the lift will be recorded if both sides of the barbell touch the bench	Maximum weight lifted (kg)	[18]
Upper body muscular power	20s push up test	Players assume prone position, body lowered until the elbows are 90 degrees, followed by a return to the starting position with arms fully extended.	Time taken to complete 20 full push ups (s)	[36]
	20s chin up test	Players assume a hanging position on the bar, hands shoulder width apart with supinated grip and arms extended. Players are to raise the body until the chin touched the top of the bar with the head in neutral position.	Maximum number of chin-ups in 20 seconds	[36]
	Overhead ball throw test	Players stand with 1 foot aligned with the a line marked on the ground facing the throwing direction, with a 3kg medicine ball held in both hands behind the head, each player is required to plant the front foot with the toe behind the line and to throw the medicine ball overhead as far as possible.	Maximum distance thrown (m)	[73]
	Chest throw test	Players throw a 2kg medicine ball horizontally as far as possible while seated with the back against the wall	Maximum distance thrown (m)	[41, 43-48, 57, 66]
	Bench throw test	Players use a self-selected hand position and lower the bar to a self-selected depth approximately 90 degrees at the elbow and then throw or propel the bar vertically as explosively as possible.	Maximum weight thrown (kgs)	[13]
Upper body muscular endurance	60s push up test	Players assume prone position, body lowered until the elbows are 90 degrees, followed by a return to the starting position with arms fully extended.	Maximum number of push-ups in 60s	[36]
	60s chin up test	Players assume a hanging position on the bar, hands shoulder width apart with supinated grip and arms extended. Players are to raise the body until the chin touched the top of the bar with the head in neutral position.	Maximum number of chin ups in 60s	[36]
	Bench Press repetitions-to-fatigue (BP RTF)	Players perform bench press repetitions as possible till fatigue at two markedly different resistances of 60-kgs and 102.5-kgs	Number of repetitions (n)	[81]

	Bench press repetitions-to-fatigue at 60% 1RM	Players perform bench press repetitions as possible till fatigue with a resistance of 60% of their one repetition maximum bench press	Number of repetitions at 60% 1RM BP	[81]
	Pull up test	Using an underhand grip, and the hands 10-15 cm apart, players start in the hanging position and ascended to a position with the chin above the bar and then return to starting position with arms extended.	Maximal number of completed pull-ups	[7]
	Body mass bench press with repetition	Using players body mass as resistance for as many repetitions as possible until fatigue	Number of repetitions (n)	[15]
	30s Plyometric push up	Participants would take a push-up position supporting self on the palm of left or right hand with the other hand placed on the top of a 5kg medicine ball. The players then lower themselves to the ground until elbows are 90 degrees; they then forcefully pushes back with complete extension of the arms, while shifting the hand on the ground across to the new position on the medicine ball. Similarly, the hand on the ball shift across to a position approximately 2 shoulder widths on the opposite side of the ball	Maximum number of repetitions in designated time period	[58]
Abdominal endurance	60s Sit up	Participants would sit with feet flat on the floor and held in position by another player. The arms would be crossed at the shoulders and knees bent at an angle approximately 90 degrees. On command, the players would curl the trunk so that elbows touch the front of the thighs and then return to starting position	Maximum number of repetitions in 60s	[58]

VO_{2max}-maximal aerobic power estimated using regression equations; s=seconds;* calculated as a percent change in sprint time predicted from the linearized change derived from all sprints performed; $b.min^{-1}$=beats per minute; RL=rugby league; RU=rugby union; m=meters; vVO_{2max}=velocity at maximal oxygen uptake also known as MAS (maximal aerobic speed); ASR=Anaerobic speed reserve calculated as the difference between individual maximum velocity (maxV) and MAS;N=newton; n=number of repetitions; kgs=kilograms; 1RM bench press=one repetition maximum bench press.

Appendix L: Stage 2 search strategy

((psychometrics OR psychometric property OR clinimetr* OR clinometr* OR clinimetric property* OR measurement property OR measurement* OR measuring OR reproducib* OR reproducibility of results OR reliab* OR test-retest OR intra-rater OR inter-rater OR measurement error OR standard error of measurement OR technical error of measurement OR typical error of measurement OR sensitiv* OR responsive* OR interpretab* OR meaningful change OR minimal important change OR minimal important difference OR minimal detectable change OR minimal detectable difference OR ceiling effect OR floor effect OR valid* OR construct valid* OR face valid*or validation OR discriminative validity OR concurrent valid* OR convergent valid*))*

AND

((vertical jump test OR Countermovement jump test OR Jump squat test OR Plyometric power system OR speed test* OR sprint test OR Linear speed test OR 5m speed test OR 5m sprint test OR 10m sprint test OR 10m speed test OR 15m sprint test OR 20m sprint test OR 20m speed test OR 40m sprint test OR 40m speed test OR 50m speed test OR 50m sprint test OR 60m speed test OR 60m sprint test OR repeated 20m sprint test* OR rugby specific repeated speed test OR repeated effort ability test OR repeated high-intensity exercise performance test OR repeated 12s sprint shuttle speed test OR 5-m run test OR multistage fitness stage test* OR 20m multistage shuttle run test OR L-run test* OR 505 test OR Agility 505 test OR Illinois agility test OR modified 505 test OR Change of direction speed test OR Agility test OR yo-yo intermittent recovery (level 1) test* OR yo-yo intermittent recovery (level 2) test OR 30-15 Intermittent fitness test OR 1500m run OR 1500m run metabolic fitness index OR Triple 120m shuttle test OR Wingate 60 cycle test OR 300m shuttle run test OR 1 repetition maximum bench press test* 1 repetition maximum chin up test OR 3 repetition maximum bench press OR 1 minute push up test OR 1RM bench press OR 1RM prone row OR 60s push up test OR 60s chin up test OR 60s Sit Up OR pull up test OR 20s chin up test OR 2kg medicine ball chest throw test OR bench throw OR overhead medicine ball throw OR 1rm back squat OR 1 repetition maximum back squat OR one repetition bench press repetitions to fatigue at 60kg and 102.5kg test OR pull-up test OR body mass bench press with repetition))*

AND

((rugby OR rugby union OR rugby union team OR rugby league OR rugby player OR elite OR sub-elite OR rugby players OR collision sport* OR talented OR talent identification OR talent selection OR player assessment OR player development OR non-talented OR draft* OR non-draft* OR skilled players OR non-skilled players OR starters OR non-starters OR positional differences))*

AND

((Australian Rules football OR Australian football OR collision sport OR intermittent sport OR contact sport OR team sports OR soccer OR football OR American football OR Gaelic football OR collision sport)).

Appendix M: Characteristics of included studies from stage 2 and psychometric properties

Authors	Title	Purpose of the study	Age	Country	Sport	Test(s)	Construct measured	Properties evaluated
Austin et al (2013)[24]	Reliability and sensitivity of a repeated high- intensity exercise performance test for Rugby league and Rugby Union	To examine the reliability and sensitivity of 3 repeated high-intensity exercise tests (RHIE)	24±4 (Backs); 24±3 (RU forwards); 24±2 (RL forwards)	Australia	RL and RU	RHIE Backs test RHIE RL Forward test RHIE RU Forward test	Repeated high-intensity exercise	Reliability
Baker (2009)[81]	Ability and validity of 3 different methods of assessing upper-body strength-endurance to distinguish playing rank in professional rugby league players	To compare the ability and validity of 3 different methods of assessing strength-endurance	Study 1=20.0±1.2-24.9±3.0 years Study 2=19.5±1.7-25.0±3.3 years	Australia	RL	BP RTF 60% 1RM BP RTF 60kg BP RTF 102.5kg	Upper-body strength-endurance	Validity
Duthie et al (2006)[99]	The reliability of ten-meter sprint time using different starting techniques	To compare the reliability of 10m sprint times when using different starting techniques	17±0.7 years	Australia	RU	10m sprint test with foot start 10m sprint test with standing start 10m sprint test with thumb start	Speed	Reliability
Gabbett et al (2008)[19]	Speed, change of direction, and reactive agility of Rugby League players	To investigate the discriminative ability of speed, change of direction speed, and reactive agility tests	23.6±5.3 years	Australia	RL	5m sprint test 10m sprint test 505 test Modified 505 test Lrun test	Speed, Agility	Reliability, Validity
Green et al (2011)[6]	A valid field test protocol of linear speed and agility in Rugby Union	To investigate the reliability and construct validity of a field test	19±1.67-19±1.30 years	Ireland	RU	10m sprint test 30m sprint test Change of direction speed	Speed, Agility	Reliability, Validity

		protocol						
Holloway et al (2008)[70]	The Tripple-120 meter shuttle test: A sport-specific test for assessing anaerobic fitness in Rugby League Players	To design a sport specific test for anaerobic endurance and compare the validity of the test with the Wingate 60-second cycle test	21.5±2.15 years	Australia	RL	Tripple-120 meter shuttle test	Anaerobic endurance	Validity
Johnston and Gabbett (2011)[51]	Repeated-sprint and effort ability in Rugby League players	To assess the test-retest reliability of repeated sprint and repeated effort tests	22.7±2.2 years	Australia	RL	Repeated ability sprint test Repeated effort test	Repeated sprint ability and effort	Reliability
Serpell et al (2010)[74]	The development of a new test of agility for Rugby League.	To develop a reliable and valid agility test	>18 years	Australia	RL	Change of direction speed test	Agility	Reliability, Validity
Scott et al (2015)[68]	Reliability and usefulness of the 30-15 Intermittent fitness test in Rugby League	Examined the reliability and usefulness of the 30 Intermittent Fitness test	15.6±0.3-19.4±0.5 years	Australia	RL	30-15 Intermittent fitness test	Intermittent running ability	Reliability
Ingebrigtsen et al (2012)[97]	Yo-Yo IR2 testing of elite and sub-elite soccer players: Performance, heart rate response and correlations to other interval tests	To correlate the Yo-Yo Intermittent recovery test level 2 with other frequently used tests in elite soccer	20±3-26±7 years	Denmark and Norway	Soccer	Yo-Yo intermittent recovery test (level 2)	Prolonged high-intensity intermittent running ability	Validity
Deprez et al (2014)[88]	Reliability and validity of the Yo-yo intermittent recovery test (level 1) in young soccer players	To investigate the test-retest reliability and construct validity	12.5±0.6-16.2±0.6 years	Belgium	Soccer	Yo-Yo intermittent recovery test (level 1)	Prolonged high-intensity intermittent running ability	Reliability, Validity

		from the Yo-Yo Intermittent recovery test level 1						
Krustrup et al (2003)[89]	The Yo-yo intermittent recovery test: Physiological response, reliability and validity	To examine the reproducibility and validity of the Yo-Yo intermittent recovery test level 1	Range: 25-36 years	Denmark	Soccer	Yo-yo intermittent recovery test (level 1)	Prolonged high-intensity intermittent running ability	Reliability, Validity
Krustrup et al (2006)[98]	The Yo-Yo IR2 test: Physiological response, reliability and application to elite soccer	To examine the physiological response and reliability of the Yo-Yo intermittent recovery test level 2	Range: 22-30 years	Denmark	Soccer	Yo-yo intermittent recovery test (level 2)	Prolonged high-intensity intermittent running ability	Reliability
Markovic & Mikulic (2011)[93]	Discriminative ability of the Yo-yo intermittent recovery test (level 1) in prospective young soccer players	To evaluate the discriminative ability of the Yo-yo intermittent recovery test level 1	12.0-18.9 years	Croatia	Soccer	Yo-yo intermittent recovery test (level 1)	Prolonged high-intensity intermittent running ability	Validity
Fanchini et al (2014)[94]	Are the Yo-yo intermittent recovery test levels 1 and 2 both useful? Reliability, responsiveness and interchangeability in young soccer players	To compare the reliability, internal responsiveness and interchangeability of the Yo-Yo intermittent recovery test level 1	17±1 years	Italy	Soccer	Yo-yo intermittent recovery test (level 1) Yo-yo intermittent recovery test (level 2)	Prolonged high-intensity intermittent running ability	Reliability, Validity Responsiveness
Buchheit & Rabbani (2014)[95]	The 30-15 Intermittent fitness test versus the Yo-yo intermittent recovery test level	To examine the relationship between Yo-Yo	15.4±0.5 years	Iran	Soccer	Yo-yo intermittent recovery test (level 1)	Prolonged high-intensity intermittent	Validity, Responsiveness

	1: relationship and sensitivity to training.	intermittent recovery test and the 30-15 Intermittent Fitness test and compare the sensitivity of both tests to training					running ability	
Deprez et al (2015)[96]	The Yo-Yo intermittent recovery test level 1 is reliable in young high-level soccer players	To investigate the test-retest reliability of the Yo-yo intermittent recovery test level 1	13.9 ± 0.5-18.1 ± 0.4 years	Belgium	Soccer	Yo-yo intermittent recovery test level 1	Prolonged high-intensity intermittent running ability	Reliability
Da Silva et al (2011)[91]	Yo-Yo IR2 and Margaria test: Validity, reliability and maximum heart rate in young soccer players	To evaluate the reliability, construct validity of the Yo-Yo intermittent recovery test and of the Margaria test.	14±0.8 years	Brazil	Soccer	Yo-Yo intermittent recovery test (level 2)	Prolonged high-intensity intermittent running ability	Reliability, Validity
De Salles et al (2012)[90]	Validity and reproducibility of the Sargent jump test in the assessment of explosive strength in soccer players	To check the validity, inter and intra-evaluators reproducibility of the Sergeant jump test.	14.3±0.66 years	Brazil	Soccer	Sargent (vertical jump) jump test	Lower-body muscular power	Reliability, Validity
Veale et al (2010)[92]	The Yo-yo intermittent recovery test (level 1) to discriminate elite junior Australian football players	To evaluate the discriminative validity of the Yo-yo intermittent recovery test	16.6±0.5 years	Australia	Australian football	Yo-Yo intermittent recovery test (level 1)	Prolonged high-intensity intermittent running ability	Validity

Bench press repetition-to-fatigue with resistance at 60% 1RM= BP RTF 60% 1RM; Bench press repetition-to-fatigue with resistance at 60kg and 102.5kg=BP RTF 60kg and BP RTF 102.5kg.

Appendix N: Second review search strategy

First step

Rugby-specific skill OR game specific skill* OR rugby skill* OR technical skill**

AND

Adult OR senior OR adolescent OR youth OR teenager* OR elite OR sub-elite OR male OR U-16 players OR U-19 players OR professional OR amateur*

AND

Rugby OR rugby union OR rugby union team OR rugby league OR rugby player OR elite rugby players*

AND

Test OR screening* OR measure**

Second step

Rugby-specific skill OR game specific skill* OR rugby skill* OR technical skill**

AND

Adult OR senior OR adolescent OR youth OR teenager* OR elite OR sub-elite OR male OR U-16 players OR U-19 players OR professional OR amateur*

AND

Rugby OR rugby union OR rugby union team OR rugby league OR rugby player OR elite rugby players*

AND

Test OR screening* OR measure**

AND

Psychometrics [MeSH] OR psychometr OR psychometric property* OR clinimetr* OR clinometr* OR clinimetric property* OR measurement property OR reproducibility of results [MeSH] OR reproducib* OR reliab* OR test-retest OR intra-rater OR inter-rater OR co-efficient OR internal consistency OR alpha cronbach* OR measurement error OR valid* OR construct valid* OR content valid* OR face valid* OR validation OR discriminative*

Appendix O: First version of the SCRuM test battery and rationale for inclusion of tests

SCRuM variables	Test selection criteria					Test included	Reason(s) for inclusion
	[a]Test commonly used in literature	Rugby-specific test identified	Test commonly used locally	[a]Test with sound psychometric properties	[a]Level of evidence for the test [59]		
Speed	10m, 20m, 40m linear speed tests	None	5m-60m linear speed drills	5m, 10m, 20m	Limited evidence for test-retest reliability (+) rating for 5m, 10m, 20m speed test; Limited evidence for construct validity (+) rating for 5m, 10m, 20m speed tests only.	5m, 10m, 20m, 40m linear speed tests.	**5m, 10m, 20m** chosen based on better psychometric properties. **40m** speed test incorporated because it is part of speed tests commonly used in the literature and mimics the match demands of longer sprints characteristic of the back players.
Repeated sprinting ability (RSA)	Repeated 20m sprint test	Rugby-specific repeated speed (RS^2) test	*Repeated speed drills for variable distances	None	None	Rugby-specific repeated speed (RS^2) test.	**RS^2** test was specifically developed for rugby. The test has face validity for assessment of repeated sprinting ability; it mimics the movement patterns (LIA and HIA) of the sport.
Repeated effort ability (REA)	REA test	REA test	*Not distinctly assessed.	None	None	REA test	**REA** test commonly-used in the literature; partly rugby-specific with tackling efforts in the procedure of repeated sprints.
Repeated high-intensity exercise (RHIE)	RHIE performance test	RHIE performance	*Not distinctly assessed	None	None	Repeated high intensity exercise	**RHIE** performance test is commonly used, has face validity for assessment of

performance		test				(RHIE) performance test	repeated high intensity activities.
Prolonged high-intensity intermittent running ability/endurance	Yo-yo intermittent recovery level 1test (Yo-Yo IRT 1)	None	Beep test	None	None	Yo-yo intermittent recovery test level 1	**Yo-Yo IRT 1** is commonly used in literature and in local context.
Maximal aerobic power (MAP)	Multistage fitness (MSF) test	None	None	None	None	Multistage fitness (MSF) test	**MSF** test commonly used for assessment of MAP.
Anaerobic endurance or capacity	Triple 120m shuttle (T120S) test Wingate 60 (w60) cycle test 300m shuttle run test 400m sprint test (Metabolic Fitness Index for Team Sports)	None	*Not distinctly assessed.	None	None	Triple 120m shuttle (T120S) test	**T120S** mimics rugby demands, has face validity for assessing anaerobic capacity as compared to other identified tests.
Change of direction speed/agility	505 test	None	L-run, Illinois agility run test	Modified 505 test	Limited evidence for test-retest reliability of modified 505 test (+) rating [ICC=0.92; TE%=2.5]	L-run	**L-run test** used commonly locally and has fair psychometric properties with relatively high ICC when compared to other agility tests (modified 505 test and 505 test).
					Limited evidence on construct validity for modified 505 test (-) rating (ES=0.32)		

				L-run	Limited evidence for test-retest reliability on L-run test (+) rating [ICC=0.95; TE%=2.8]		
					Limited evidence on the construct validity for L-run test (-) rating (ES=0.28)		
				505	Limited evidence for test-retest reliability on 505 test (+) rating [ICC=0.90;TE%=1.9]		
					Limited evidence on the construct validity for 505 test (-) rating (ES=0.28).		
Lower body muscular power	Countermovement jump (CMJ) test	None	Vertical jump (VJ) test	VJ test	Limited evidence for intra [ICC=0.99] and inter-rater reliability [ICC=1.00] (+) rating	VJ test	**VJ test** is locally used and has better psychometrics compared to other tests for power
Lower body muscular strength	One repetition maximum back squat test (1RM BS)	None	U19-back squat U13-U16-wall sit leg strength, functional squats test	None	None	One repetition maximum back squat test (1RM BS)	**1RM BS** is the most commonly used test in the literature
Upper body muscular power	2-kg medicine ball chest throw (2-kg MBCT)	None	None	None	None	2kg MBCT	**2kg MBCT** is commonly used in the literature

Upper body muscular strength	One repetition maximum bench press (1-RM BP)	None	U16-Push up test, flexed arm hang test	None	None	One repetition maximum bench press (1RM BP)	**1RM BP** is commonly assessed in the literature
			U20-bench press				
**Upper body muscular endurance	60s push-up test	None	Flexed arm hang	BP RTF 60 kg and BP RTF 102.5kg	These two tests had limited evidence on known group validity (+) rating.	Flexed arm hang	**Flexed arm hang** has a similar procedure as the pull-up test and local coaches are also familiar with its use.
	60s chin up						
	1-RM Bench press repetitions-to-fatigue at 60kg						
	1-RM Bench press repetitions-to-fatigue at 102.5kg						**BP RTF 60 kg and BP RTF 102.5kg** has better psychometrics but the tests use massive weight load.
	Pull up test						
	Body mass bench press with repetition; 30s plyometric push-up test						
Abdominal endurance	60s sit up test	None	Sit ups	None	None	60s sit up	**60s sit up** is commonly used in literature and locally
Reactive agility	Reactive agility test (RAT)	None	None	Reactive agility test	Moderate evidence on test-retest reliability for total reactive agility time (++)	RAT	**RAT** is commonly used in the literature and has better psychometric properties.

					rating [ICC=0.88, SEM=0.09;ICC=0.82, SEM=0.01]		
					Moderate evidence on known group validity of the reactive agility test on reactive agility speed (++) ES=1.14, ES=0.73, ES=0.56.		
Tackling	Tackling proficiency test	Tackling proficiency test	Tackling drills	None	None	Tackling proficiency test	**Tackling proficiency test** chosen because tackling is a skill commonly assessed in the literature.
Catching	Running-and-catching test	Running-and-catching test	Catching drills	Running-and-catching pass	Limited evidence on test retest reliability of the running-and-catching test (-) rating, r=0.53	Running-and-catching test	**Running-and-catching test** has better psychometric properties.
					Limited evidence for known-group validity of the running-and-catching test (w^2=23.3) + rating		
Kicking	Kicking-for-distance test	Kicking-for-distance test	Kicking test	Kicking-for-distance test	Limited evidence on known-group validity of the kicking for distance test (w^2=29.4; +rating; w^2=13.9; - rating)	Kicking-for-distance test	**Kicking-for-distance** test has been used in previous studies and has better psychometrics
Passing-for-distance	Passing-for-distance test	Passing-for-distance test	Passing tests	Passing-for-distance test	Limited evidence on the test-retest reliability of the passing-for-distance	Passing-for-distance	**Passing-for-distance** test has been used in previous studies and has better

					test (r=0.74); – rating.		psychometric properties
					Limited evidence on the construct validity of the test (w2=32.4), + rating.		
Passing-for-accuracy	Passing-for-accuracy 7m test	Passing-for-accuracy test	Passing test	Passing-for-accuracy 7m test	Limited evidence on the test-retest reliability for the passing for accuracy 7m test (r=0.66; - rating)	Passing-for-accuracy 7m test	**Passing-for-accuracy 7m** test has better psychometric properties
					Limited evidence on the known group validity for the test (w2=50.7; + rating)		
	Passing-for-accuracy 4m test	Passing-for-accuracy test	Passing test	Passing-for-accuracy 4m test	Limited evidence on the test-retest reliability for the test (r=0.39; - rating)		
					Limited evidence on the known-group validity for the test (w2=10.6; - rating)		

Appendix P: Face validity research questionnaire for key informants

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Participant code………………………………..

Demographic and rugby-related information

How old are you? (Full years attained): ____

Gender: Male ☐ Female ☐

High school rugby experience

Year started coaching rugby at this high school: ____

Total number of years coaching high school rugby overall: ____

Rugby school team coached: U16 ☐ u20 ☐ both ☐

Which league is your school in? Super Eight ☐ Co-educational Leagues ☐

Do you have any other coaching experience in rugby? Yes ☐ No ☐

If yes, please give more information ____

Personal rugby experience

Have you ever played rugby in your lifetime? Yes ☐ No ☐

If yes, at what level did you play? School ☐ Club ☐ Social ☐ All ☐

School refers to primary and high school rugby, Club refers to senior professional rugby for a team playing in a rugby league, Social refers to amateurish or recreational rugby played for fun and enjoyment.

If yes, for how many years did you play? ____

Include your current experience as well if you still play rugby at professional club or a social club

<u>Second part: Face validation of the SCRuM test items</u>

<u>Instruction</u>: Feel free to request for any sort of assistance with regards to the completion of this part of the study. Please be guided by the provided manual with the test descriptions and test procedures for the assessment of the corresponding variables.

1. Please rate whether each of the SCRuM test item appear to be measuring the identified corresponding variable using the Likert scale responses below *(1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree)*. Please put in your reasons commenting if your rating is 1, 2 or 3.

Variable	**Test**	**Likert scale responses**					**Comment**
		Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Reasons for rating1, 2, 3
Speed	5m, 10m, 20m, 40m speed test						
Repeated sprinting ability	Rugby-specific repeated speed test						
Repeated effort ability	Repeated effort ability test						
Endurance	Yo-yo intermittent recovery level 1 test						
Repeated high intensity exercise ability	Repeated high intensity exercise performance ability test						
Maximal aerobic power	Multistage fitness test						
Anaerobic capacity	Triple 120m shuttle run						
Agility	L-run test						
Lower-body strength	One repetition maximum back squat test						
Lower-body power	Vertical jump test						
Upper-body strength	One repetition maximum bench press						
Upper-body power	2-kg medicine ball chest throw test						
Upper-body muscular endurance	Flexed arm hang						
Abdominal endurance	60seconds sit up test						
Reactive agility	Reactive agility test						
Tackling	Tackling proficiency test						
Catching	Running and catching test						
Kicking	Kicking for distance test						
Passing for distance	Passing for distance test						
Passing for accuracy	Passing for accuracy test						

2. As it is, do you think the test battery appear to adequately reflect a compilation of anthropometric variables, physiological characteristics and rugby-specific game skills that are very important to measure or assess among male adolescent rugby players?

Yes ☐ No ☐

If No, please comment below or suggest other variables that require inclusion in the test battery

……
……
……
……
………………………………………………………………………………………………………..

Appendix Q: Medical Research Council of Zimbabwe (MRCZ) ethical approval

Telephone: 791792/791193
Telefax: (263) - 4 - 790715
E-mail: mrcz@mrcz.org.zw
Website: http://www.mrcz.org.zw

Medical Research Council of Zimbabwe
Josiah Tongogara / Mazoe Street
P. O. Box CY 573
Causeway
Harare

APPROVAL

REF: MRCZ/A/2070

04 July 2016

Matthew Chiwaridzo
University of Zimbabwe
College of health Sciences
Department of Rehabilitation
P.O Box A 178
Avondale
Harare

RE:- SCRUM (School Clinical Rugby Measure) :- What makes or breaks a good adolescent rugby player

Thank you for the application for reviewof Research Activity that you submitted to the Medical Research Council of Zimbabwe (MRCZ). Please be advised that the Medical Research Council of Zimbabwe has **reviewed** and **approved** your application to conduct the above titled study.

Thisapproval is based on the review and approval of the following documents that were submitted to MRCZ for review:-

a) Full Proposal
b) Parental Informed Consent Forms (English and Shona)
c) Assent Forms (English and Shona)
d) Data Collection Tools (English and Shona)

- **APPROVAL NUMBER** : **MRCZ/A/2070**

This number should be used on all correspondence, consent forms and documents as appropriate.

- **TYPE OF MEETING** : **Full Board**
- **EFFECTIVE APPROVAL DATE** : **04 July 2016**
- **EXPIRATION DATE** : **03 July 2017**

After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the MRCZ Offices should be submitted three months before the expiration date for continuing review.

•SERIOUS ADVERSE EVENT REPORTING: All serious problems having to do with subject safety must be reported to the Institutional Ethical Review Committee (IERC) as well as the MRCZ within 3 working days using standard forms obtainable from the MRCZ Offices or website.

•MODIFICATIONS: Prior MRCZ and IERC approval using standard forms obtainable from the MRCZ Offices is required before implementing any changes in the Protocol (including changes in the consent documents).

•TERMINATION OF STUDY: On termination of a study, a report has to be submitted to the MRCZ using standard forms obtainable from the MRCZ Offices or website.

•QUESTIONS: Please contact the MRCZ on Telephone No. (04) 791792, 791193 or by e-mail on mrcz@mrcz.org.zw

Other

- Please be reminded to send in copies of your research results for our records as well as for Health Research Database.
- You're also encouraged to submit electronic copies of your publications in peer-reviewed journals that may emanate from this study.

Yours Faithfully

Signature Removed

MRCZ SECRETARIAT
FOR CHAIRPERSON
MEDICAL RESEARCH COUNCIL OF ZIMBABWE

MEDICAL RESEARCH COUNCIL OF ZIMBABWE
2016 -07- 04
APPROVED
P.O. BOX CY 573 CAUSEWAY, HARARE

PROMOTING THE ETHICAL CONDUCT OF HEALTH RESEARCH

Appendix R: Key informant information letter and informed consent

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Dear **Key informant**

My name is Matthew Chiwaridzo. I am a PhD student at the University of Cape Town, South Africa. I am conducting a research project entitled: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player***". My research team includes my supervisors: Professor Bouwien Smits-Engelsman and Dr Gillian Ferguson from University of Cape Town, and research assistants from the University of Maastricht in the Netherlands and from the University of Zimbabwe. I would like to invite you to participate in my research study. To help you make an informed decision regarding your participation in this study, I have prepared some information for you below.

PURPOSE OF THE STUDY

This study will be conducted in three continuous phases. You are invited to participate in the second phase of the project which is the face validation study. The purpose of this part of the study is to determine test items to be included in the SCRuM test battery based on your opinion of test measuring physical, physiological qualities and game specific skills. We have developed a test battery which we hope to use to identify good rugby players with and now we want to find out if we have included all that matters in terms of the test items in the SCRuM test battery. This information will help us in refining and further developing the test battery so that it can be used in further studies.

WHY HAVE I CONTACTED YOU?

I have contacted you because you are currently working as a high school rugby coach in a school that has rugby as a sport or you are coaching a school that is competing either in the Super Eight Schools Rugby League. Your experience as a rugby coach is very important to this study and is all I need to be able to answer the questions that I have and makes you a rugby key informant for this study.

WHAT WILL YOU BE ASKED TO DO?

A questionnaire will be given to you and will probably take 20 minutes of your time to complete.

ARE THERE RISKS INVOLVED?

There are no risks involved with the study since the study involves answering questions on a questionnaire. There are no right or wrong answers. Feel free to express your opinion explicitly. The researcher will value and respect all your contribution and will not judge you based on your answers. The researcher may ask further questions to seek clarity on any answer you provide.

WHAT WILL I GET IF I TAKE PART?

There is no payment for taking part in the study. I hope at the conclusion of this study the information gathered will benefit you, your school and the nation at large in knowing the skills and qualities to look for, to train in young adolescent male rugby players, and the tests that coaches can use to screen for talented rugby players and for players with increased risk of getting injured.

IS PARTICIPATION VOLUNTARY?

Participation in the study is entirely voluntary. You are not under an obligation to participate. Your refusal to participate will be respected and no repercussions will follow that and there is no need to provide an explanation. You have no obligation to remain in the study or participate in subsequent follow-up studies to this one conducted at your school. You can withdraw at any point without consequences nor the need to provide an explanation.

WILL PEOPLE KNOW WHAT ANSWERS I HAVE GIVEN?

No one will know what answers you gave except the researchers. All the information obtained from you will be used specifically for this study. You are encouraged not to discuss your answers or consult with other coaches after reading this letter or even after the questionnaire administration. Your name or school name will not be given to anyone and will not be listed anywhere. The questionnaires will be kept in the principal investigator office at the University of Zimbabwe, College of Health Sciences at Parirenyatwa hospital in the Department of Rehabilitation in a locked cupboard for the period of the whole study (3 years). The information will only be destroyed two years after the conclusion of the study. However, the results of this project will be made available to the schools that participate through a copy of the binded thesis. The results will also be published in journals for the global audience but will not be linked to you in any way.

IS THE STUDY APPROVED?

I have been given ethical approval by Human Research Ethics Committee in South Africa and the Medical Research Council of Zimbabwe to conduct the study. These committees make sure that people who take part in research are protected. I have provided contact details for these ethical committees at the end of this information letter in case you want to verify the details of this study. I have also obtained institutional approval from the Ministry of Primary and Secondary Education and your school headmaster to conduct the study at this school.

WHO TO CONTACT FOR MORE INFORMATION?

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. For more queries, you may contact the Faculty of Health Sciences, Human Research Ethics Committee (+27 21 406 6338) through their chairman, Professor Marc Blockman for any questions or concerns regarding your rights or welfare as a participant in this study. Locally, you contact the Registrar at the Medical Research Council of Zimbabwe on the following numbers +263 4 791792. Should you have any questions regarding the study, you may contact the principal investigator (Matthew Chiwaridzo) on the following number +263 773 603 069 or through email at matthewchiwaridzo@yahoo.co.uk. My physical address is University of Zimbabwe, College of Health Sciences, Rehabilitation Department, Room 41, Ground Floor, New Health Sciences Building, P.O Box A178 Avondale, Harare, Zimbabwe. You may also contact my supervisor, Professor Bouwien Engelsman on bouwiensmits@hotmail.com. Additionally, contact my co-supervisor from the University of Cape Town, Dr Gillian Ferguson at this email address, gillian.ferguson@uct.ac.za or at the following physical address as well, Division of Physiotherapy Department of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town, Tel: +27 21 406 6045.

Your cooperation is greatly appreciated. If you chose to participate, please sign the attached informed consent form.

Yours faithfully,

Matthew Chiwaridzo

Signature……………………………………………..

Date………………………………………………….

Informed consent form

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Study title: SCRuM (School Clinical Rugby Measure): ***"SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***

Institution: University of Cape Town, Faculty of Health Sciences, Division of Physiotherapy

I --have read the information sheet given to me by Matthew Chiwaridzo. I understand he is conducting a research study. I understand what is required of me and I have had all my questions answered. I do not feel that I am forced to take part in this study and I am doing so on my free will. I know that I can withdraw at any time if I so wish and that it will have no bad consequences for me.

Signed:

-- --

Participant Date and place

-- --

Researcher Date and place

-- --

Witness Date and place

Thank you very much for your support

Appendix S: Logical validation questionnaire

	School of Health and Rehabilitation Sciences **Faculty of Health Sciences** Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Instruction: *Please feel free to provide the information being elicited below which will be used purely for descriptive purposes of the sample of panel of experts used during this part of the study.*

Participant code……………………………………………

Section A: Demographic and rugby related information

- Age (full years attained)……………………………………………………………………………
- Gender: Male ☐ Female ☐
- Profession:

i. Senior Adult Rugby Coach ☐
ii. Junior Rugby Coach ☐
iii. Current Rugby Player ☐
iv. Former Rugby Player ☐
v. Local Sports Scientist/Researcher ☐
vi. International sport scientist/researcher ☐
vii. National Rugby Director ☐
viii. Technical Team Member ☐
Other (specify)…………………………………………………………………………………

- Total number of years involved in rugby…………………………………………………..

Section B: Content validation of the SCRuM test battery

Please complete the following table judging the relevance of each item for inclusion in the SCRuM test battery on a scale of 1 to 4 (*1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 =highly relevant.*

Instruction: *Relevance should be judged on the characteristics self-perceived to be important in the sport of rugby and could be used to discriminate successful rugby players from less successful rugby players.*

Please provide a simple comment for any item you rated 1 or 2.

	Relevance				
SCRuM test battery items	**1**	**2**	**3**	**4**	**Comment**
Speed					
Repeated sprinting ability					
Repeated effort ability					
Repeated high intensity exercise performance ability					
Prolonged high-intensity intermittent recovery ability/Endurance					
Anaerobic capacity					
Change of direction speed/agility					
Lower-body muscular power					
Lower-body muscular strength					
Upper-body muscular strength					
Upper-body muscular power					
Upper-body muscular endurance					
Abdominal endurance					
Reactive agility					
Tackling					
Catching					
Kicking					
Passing for distance					
Passing for accuracy					
Height					
Weight					
Skin folds					

2. List any other physical attributes, characteristics or rugby-specific game skills that are not mentioned or included above that you consider **extremely important** for them to be included in the SCRuM test battery for the battery to be adequately comprehensive (*You can provide as many as you can*). Feel free to use the empty spaces below to write all your possible answers.

1……
2……
3………………………………………………………………………………………………………..
4……
5…….
6……

3. Please indicate possible corresponding tests which you recommend for the testing of each of the physical or physiological characteristics, skills or attributes you identified or mentioned above. (*You can provide as many tests as you can for each construct*)

Characteristic, skill or attribute	**Method of assessment/applicable test**
1	
2	
3	
4	
5	
6	
7	

THANK YOU FOR PARTICIPATION

Appendix T: Information sheet and informed consent for content experts

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Dear Content Valid Expert

My name is **Matthew Chiwaridzo**. I am a PhD student at the University of Cape Town, South Africa. I am conducting a research project entitled: ***"SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***. I am a Physiotherapist by profession and I am currently employed as a Physiotherapy lecturer at the University of Zimbabwe, College of Health Sciences. My research team includes my supervisors: Professor Dr Bouwien Smits-Engelsman and Dr Gillian Ferguson from University of Cape Town, and research assistants from the University of Maastricht in the Netherlands and from the University of Zimbabwe. I would like to invite you to participate in my research study as a content validity expert for the newly assembled test battery dubbed the SCRuM (School Clinical Rugby Measure). To help you make an informed decision regarding your participation in this study, I have prepared some information for you below.

PURPOSE OF THE STUDY

The study is part of a much broader research project ultimately aimed at identifying the characteristics that determine a good adolescent rugby player in Harare, Zimbabwe. The study has three phases. The first phase led to the development of the SCRuM test battery through a process guided by a narrative literature review, small-scale qualitative study exploring local rugby coaches' perception on the attributes, qualities or skills that are needed in rugby and systematic review on the psychometric properties of commonly used physiological and game specific skills tests. The purpose of this part of the study is to determine test items in the newly assembled SCRuM test battery and evaluate their content or logical validity to be included in the test battery. The main objective of developing the test battery was to have a multi-dimensional screening tool which can be used in the local context to identify "good" young rugby players. Therefore, this part of the study aims to fine tune the SCRuM test battery by selecting or recommending for addition qualities or skills and their corresponding tests that are important in rugby.

WHY HAVE I CONTACTED YOU?

The decision to contact you was premised on the need to have a panel of experts which was representative of all the stakeholders involved in the modern game of rugby. I have contacted you as a local or international expert because of one of the following reasons:

1. Perhaps you are senior adult coach for the Zimbabwe national team rugby or one of the top five professional rugby clubs playing in the National Rugby league in Harare, Zimbabwe. Your experience as a coach at this highest level will help us in fine-tuning the SCRuM test battery.
2. Perhaps you are also a junior rugby coach at the high schools that participate in the Super Eight Schools Rugby League. This league represents the most competitive league in the country as far as adolescent youth rugby is concerned. Your experience as a coach in that organised league will also assists us in fine tuning the SCRuM test battery.
3. By virtue of your position as the national association rugby director. Your experience as the director of rugby in the country will also assist us in refining the SCRuM test battery.
4. By virtue of your current status as a senior rugby player for a professional club playing in the National Rugby League.
5. By virtue of your past rugby experience as a former player for the Zimbabwe national rugby team and having had international exposure in professional rugby.
6. By virtue of your position as member of the technical team for a rugby team as a fitness trainer or physiotherapists for the team.
7. Perhaps you are an enthusiastic rugby analyst from a reputable mass media house and your enriched knowledge on rugby can assist fine tuning the SCRuM test battery.
8. Perhaps you are sports scientists or lead researcher in rugby and related sports and you have written many peer-reviewed journal articles available online on the sport of rugby.

WHAT WILL YOU BE ASKED TO DO?

This study entails evaluating whether each characteristic or skill and their corresponding tests in the test battery can be included in the second version of the SCRuM test battery denoting relevance of the item. Each content expert will be asked to rate each SCRuM item on a scale of 1-4 judging the relevance of each item for it to be included in a test battery.

ARE THERE RISKS INVOLVED?

There are no risks involved with the study since the study involves answering questions in a questionnaire format. There are no right or wrong answers. Feel free to express your opinion explicitly regarding the relevance of each item in the SCRuM test battery and feel free to suggest any other qualities or skills that need to be added on the test battery or omitted. The researcher will value and respect all your contribution and will not judge you based on your answers. However, the researcher may ask further questions to seek clarity on any answer you provide.

IS PARTICIPATION VOLUNTARY?

Participation in the study is entirely voluntary. You are not under an obligation to participate. Your refusal to participate will be respected and no repercussions will follow that and there is no need to provide an explanation. You can withdraw at any point without consequences or the need to provide an explanation.

WILL PEOPLE KNOW WHAT ANSWERS I HAVE GIVEN?

No one will know what answers you gave except the researchers. All the information obtained from you will be used specifically for this study. You are encouraged not to discuss your answers or consult with other coaches after reading this letter or even after the interview. Your name or school name or any other details will not be given to anyone and will not be listed anywhere. The content validation forms will be handled as sensitive material by the research team and will be handled with due care after the interview. They will be kept in the principal investigator office at the University of

Zimbabwe, College of Health Sciences at Parirenyatwa hospital in the Department of Rehabilitation in a locked cupboard for the period of the whole study (3 years). The information will only be destroyed two years after the conclusion of the study. The results will also be published in journals for the global audience but will not be linked to you in any way.

IS THE STUDY APPROVED?

I have been given ethical approval by Human Research Ethics Committee in South Africa and the Medical Research Council of Zimbabwe to conduct the study. These committees make sure that people who take part in research are protected. I have provided contact details for these ethical committees at the end of this information letter in case you want to verify the details of this study. I have also obtained institutional approval from the Ministry of Primary and Secondary Education and your school headmaster to conduct the study at this school.

WHO TO CONTACT FOR MORE INFORMATION?

Before you accept to participate in this study, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. For more queries, you may contact the Faculty of Health Sciences, Human Research Ethics Committee (+27 21 406 6338) through their chairman, Professor Marc Blockman for any questions or concerns regarding your rights or welfare as a participant in this study. Locally, you contact the Registrar at the Medical Research Council of Zimbabwe on the following numbers +263 4 791792. Should you have any questions regarding the study, you may contact the principal investigator (Matthew Chiwaridzo) on the following number +263 773 603 069 or through email at matthewchiwaridzo@yahoo.co.uk. My physical address is **University of Zimbabwe, College of Health Sciences, Rehabilitation Department, Room 41, Ground Floor, New Health Sciences Building, P.O Box A178 Avondale, Harare, Zimbabwe**. You may also contact my supervisor, Professor Bouwien Engelsman on bouwiensmits@hotmail.com. Additionally, contact my co-supervisor from the University of Cape Town, Dr Gillian Ferguson at this email address, gillian.ferguson@uct.ac.za or at the following physical address as well, **Division of Physiotherapy Department of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town**, Tel: +27 21 406 6045. Your cooperation is greatly appreciated. If you chose to participate, please sign the attached informed consent form.

Yours faithfully,

Matthew Chiwaridzo

Signature……………………………………………..

Date…………………………………………………..

Informed consent form

	School of Health and Rehabilitation Sciences **Faculty of Health Sciences** Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Study title: SCRuM (School Clinical Rugby Measure):***"SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***.

Institution: University of Cape Town, Faculty of Health Sciences, Division of Physiotherapy

I --have read the information sheet given to me by Matthew Chiwaridzo. I understand he is conducting a research study. I understand what is required of me and I have had all my questions answered. I do not feel that I am forced to take part in this study and I am doing so on my free will. I know that I can withdraw at any time if I so wish and that it will have no bad consequences for me.

Signed:

--- ---------------------------------------

Participant date and place

-- ---------------------------------------

Researcher date and place

-- ---------------------------------------

Witness date and place

Thank you very much for your support

Appendix U: Practical feasibility study questionnaire for rugby coaches

	School of Health and Rehabilitation Sciences **Faculty of Health Sciences** Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Participant Reference number/Code… Date……………………………..

Instructions: Please complete the following questionnaire to the best of your knowledge.

Section A: Demographic data and rugby related information

Age (full years attained): ____

Gender: Male ☐ Female ☐

Current School/Club ……………………………………………

Type of School Government ☐ Private ☐

High school rugby experience

1. For how many years in total have you been coaching school rugby/club…………………………………
2. Which year did you start coaching rugby at this particular school/club……………………………………
3. Which school teams have you coached since joining the school (Please tick all that apply): U13 ☐ U14 ☐ U15 ☐ U16 ☐ U17 Second team ☐ First team☐.
4. Which high school rugby league does your school participate during the winter rugby games? Super Eight ☐ Co-educational League ☐ Interscholastic rugby league ☐

(*NB: Interscholastic refers to the local rugby competitions schools engage with the neighbouring schools within the same location*)

Other coaching experience

5. Do you have any other coaching experience in rugby besides school or club rugby? Yes ☐ No ☐
6. If yes, state where else you have coached or still coach besides school/club rugby ………………………………………………………………………………………… …………………………………………………………………………………………

Personal rugby experience

7. Have you ever played organised rugby in your lifetime either school or club level? Yes ☐ No ☐
8. If yes, at what level did you play? Please tick all that applies. School ☐ Local Senior Club ☐ International Professional Club ☐ Social/amateur local and international club level ☐ Zimbabwe National Team ☐ Other (specify)……………………

School refers to primary and high school rugby, local senior club refers to a senior professional rugby club that played in the Zimbabwe national rugby league, Social refers to amateurish or recreational rugby played for fun and enjoyment in Zimbabwe or abroad. Zimbabwe national team refers to having played for the country.

9. If yes, for how many years in total did you play rugby as a player at any of the levels you mentioned above? ....
..

Include your current experience as well if you are still playing rugby at professional club or a social club

<u>Section B: Feasibility data scoring sheet</u>

10. Please complete the following table on self-perceived feasibility of each item in the SCRuM test battery based on the information provided for each test.

Instruction: *Use the following scoring criteria to rate the practical feasibility of each item in the SCRuM test battery (0=not feasible, 1=somewhat feasible, 2= feasible). Circle the most appropriate response. For logical acceptability, please rate as No (which will be awarded a score of 0), Maybe (which will be awarded a score of 1) and Yes (which will be awarded a score of 2). Circle the most appropriate response. Please use the information provided in the information document to help you answer this section.*

Test	Feasibility parameters									
	Equipment	Procedure	Possible modifications	Cost Analysis	Average duration	Human resources needed	Age-specific	Logical acceptable	Scoring and interpretation	Safety
Height	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Weight	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Skin folds	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
5m, 10m, 20m, 40m	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Repeated high intensity exercise performance	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Yo-Yo Intermittent recovery test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Sit and reach test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
1RM back squat	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
1RM bench press	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
L-run test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Vertical jump test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
2kg medicine ball chest throw test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2

Triple 120m shuttle run	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Reactive agility test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Tackling proficiency test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Running-and-catching test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2
Passing-for-accuracy test	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	0 1 2	No Maybe Yes	0 1 2	0 1 2

11. For each test that scores poor on practical feasibility (**that is a score of 0 and No for logical acceptability**) please indicate below the **areas of most concern** to you for the practical feasibility of the test and if possible provide a recommendation for the concern which may enable the test to be performed feasibly in the local context.

Test	**Areas of concern for the test**	**Tick**	**Other concerns**	**Recommendation for improvement**
5m, 10m, 20m, 40m tests	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. The modifications not changing the practicality of test			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate for adolescents			
	j. The test not logically acceptable or appropriate for rugby			
Repeated high intensity exercise performance test	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. modifications not making the test practicable			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Yo-Yo Intermittent recovery test	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. modifications not making test practical			
	e. Time consuming to perform			

	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
L-run	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the test practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Vertical jump test	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the test practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
2kg medicine ball chest throw	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the test practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			

	j. The test not logically acceptable or appropriate for rugby			
1RM bench press	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Sit and reach test	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
1RM back squat	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Reactive agility	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			

	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Tackling proficiency test	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Running and Catching test	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Passing for accuracy test	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			

	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Triple 120m shuttle run test	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Weight	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			
Height	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the tests practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			

	j. The test not logically acceptable or appropriate for rugby			
Skinfolds measures	a. A lot of equipment needed			
	b. Difficult to execute the testing procedure			
	c. Expensive to purchase the equipment			
	d. Modifications not making the test practical			
	e. Time consuming to perform			
	f. Not simple to score and interpret findings			
	g. The test involves a lot of human resources			
	h. Safety concerns high			
	i. The test not age appropriate			
	j. The test not logically acceptable or appropriate for rugby			

Appendix V: Information sheet and consent form for the feasibility study

	School of Health and Rehabilitation Sciences **Faculty of Health Sciences** Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Dear Coach,

My name is Matthew Chiwaridzo. I am a PhD student at the University of Cape Town, South Africa. I am doing a research project entitled: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player***". My research team includes my supervisors: Professor Bouwien Smits-Engelsman and Dr Gillian Ferguson from University of Cape Town, and research assistants from the University of Maastricht in the Netherlands and from the University of Zimbabwe. I would like to invite you to participate in my research study. To help you make an informed decision regarding your participation in this study, I have prepared some information for you below.

PURPOSE OF THE STUDY

The whole study will be conducted in three continuous phases. You are invited to participate in the part of the project called the "feasibility" study. The purpose of this part of the study is to determine among local school rugby coaches whether a newly developed test battery called the SCRuM can be adopted for use in the local context by evaluating each test in the SCRuM and rating its relevance, practicability and simplicity in the local context. Tests commented to be relevant, practical or simple by many will then be compiled to form the second version of the SCRuM test battery.

WHY HAVE I CONTACTED YOU?

I have contacted you because you are currently working as a high school rugby coach in a school that is competing either in the Super Eight Schools Rugby League or the Co-educational Schools Rugby League in Harare, Zimbabwe. Your experience as a rugby coach is very important to this study. The schools participating in this study were selected based on the purpose of the study which seeks to find out how feasible the test items of the SCRuM are from the coaches who are likely to use the test battery in their schools once developed.

WHAT WILL YOU BE ASKED TO DO?

You will be asked to complete a questionnaire which is anticipated to take 15 minutes to complete. The first section of the questionnaire will elicit demographic and rugby-related information which will assist us in describing the profile of coaches that participated in the study. The second part of the questionnaire will then ask you to rate each test in the SCRuM test battery for relevance, practicality and simplicity. All the instructions will be provided on the questionnaire.

ARE THERE RISKS INVOLVED?

There are no risks involved with the study.

WHAT WILL I GET IF I TAKE PART?

There is no payment for taking part in the study. We hope that the information gathered will help us in knowing tests that are practically feasible to be used in the local context. Nothing bad will happen to you if you do not take part. Refusal to take part or withdrawing from the study will not affect your current or future employment at the school or with the Ministry of Primary and Secondary Education.

IS PARTICIPATION VOLUNTARY?

Participation in the study is entirely voluntary. You are not under an obligation to participate. Your refusal to participate will be respected and no repercussions will follow that and there is no need to provide an explanation. You have no obligation to remain in the study and you can withdraw at any point neither without consequences nor need to provide an explanation.

WILL PEOPLE KNOW WHAT ANSWERS I HAVE GIVEN?

No one will know what answers you gave except the researchers. All the information obtained from you will be used specifically for this study. To ensure your confidentiality, the questionnaires should be completed in a private room free from disturbances. You are encouraged not to discuss your answers or consult with other participants whether formally or informally. Your name or school name will not be given to anyone and will not be listed anywhere. Returned questionnaires will be handled as sensitive material by the research team and will be handled with due care. They will be kept in the principal investigator office at the University of Zimbabwe, College of Health Sciences at Parirenyatwa hospital in the Department of Rehabilitation in a locked cupboard for the period of the whole study. The hard copies will be destroyed after two years following a release of a published article which utilise that data. However, the results of this project will be made available to the schools that participate and the global audience through publication but will not be linked to you in any way.

IS THE STUDY APPROVED?

I have been given ethical approval by Human Research Ethics Committee in South Africa and the Medical Research Council of Zimbabwe to conduct the study. These committees make sure that people who take part in research are protected. I have provided contact details for these ethical committees at the end of this information letter in case you want to verify the details of this study. I have also obtained institutional approval from the Ministry of Primary and Secondary Education and your school headmaster to conduct the study at this school.

WHO TO CONTACT FOR MORE INFORMATION?

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. For more queries, you may contact the Faculty of Health Sciences, Human Research Ethics Committee (+27 21 406 6338) through their chairman, Professor Marc Blockman for any questions or concerns regarding your rights or welfare as a participant in this study. Locally, you contact the Registrar at the Medical Research Council of Zimbabwe on the following numbers +263 4 791792. Should you have any questions regarding the study, you may contact the principal investigator (Matthew Chiwaridzo) on the following number

+263 773 603 069 or through email at matthewchiwaridzo@yahoo.co.uk. My physical address is **University of Zimbabwe, College of Health Sciences, Rehabilitation Department, Room 41, Ground Floor, New Health Sciences Building, P.O Box A178 Avondale, Harare, Zimbabwe**. You may also contact my supervisor, Professor Bouwien Engelsman on bouwiensmits@hotmail.com. Additionally, contact my co-supervisor from the University of Cape Town, Dr Gillian Ferguson at this email address, gillian.ferguson@uct.ac.za or at the following physical address as well, **Division of Physiotherapy Department of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town**, Tel: +27 21 406 6045.

Your cooperation is greatly appreciated. If you chose to participate, please sign the attached informed consent form.

Yours faithfully,

Matthew Chiwaridzo

University of Cape Town PhD Student

Signature………………………………………..

Date……………………………………………...

Informed consent form

	School of Health and Rehabilitation Sciences **Faculty of Health Sciences** Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy F45 Old Main Building, Groote Schuur Hospital,

Study title: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player***".

Institution: University of Cape Town, Faculty of Health Sciences, Division of Physiotherapy

I ---have read the information sheet given to me by Matthew Chiwaridzo. I understand what is required of me and I have had all my questions answered. I do not feel that I am forced to take part in this study and I am doing so on my free will. I know that I can withdraw at any time if I so wish and that it will have no bad consequences for me.

Signed:

-- --

Participant date and place

--- --

Researcher date and place

-- --

Witness date and place

Appendix W: Letter of approval from Ministry of Primary and Secondary Education

All communications should be addressed to "The Secretary for Primary and Secondary Education"
Telephone: 799914 and 705153
Telegraphic address : "EDUCATION"
Fax: 791923

ZIMBABWE

Reference: C/426/3 Harare
Ministry of Primary and
Secondary Education
P.O Box CY 121
Causeway
Harare

19 January 2016

Matthew Chiwaridzo
University of Zimbabwe
College of Health Sciences
Rehabilitation Department
P. O. Box A178
Avondale
Harare

RE: PERMISSION TO CARRY OUT RESEARCH IN HARARE PROVINCE: ST GOERGES COLLEGE, EAGLESVALE, PRINCE EDWARD, CHURCHILL, HELLENICS, GATWAY AND ST JOHNS HIGH SCHOOLS

Reference is made to your application to carry out a research at the above mentioned schools in Harare Province on the research title:

"SCHOOL CLINICAL RUGBY MEASURE (SCRuM): WHAT MAKES OR BREAKS A GOOD ADOLESCENT RUGBY PLAYER."

Permission is hereby granted. However, you are required to liaise with the Provincial Education Director Harare, who is responsible for the schools which you want to involve in your research. You should ensure that your research work does not disrupt the normal operations of the school.

You are required to provide a copy of your final report to the Secretary for Primary and Secondary Education by December 2018.

E. Chinyowa
Acting Director: Policy Planning, Research and Development
For: **SECRETARY FOR PRIMARY AND SECONDARY EDUCATION**
cc: PED – Harare Province

r/amchiwaridzoatm16

Appendix X: Letter of approval from Harare Province Education Director Office

All communications should be addressed to
"THE PROVINCIAL EDUCATION DIRECTOR"

Telephone : 792671-9
Fax : 796125/792548
E-mail :
moeschre@yahoo.com

ZIMBABWE

REF: G/42/1
Ministry of Education, Sport and Culture
Harare Provincial Education Office
P. O. Box CY 1343
Causeway
Zimbabwe

8/02/16

Matthew Chiwaridzo
University of Zimbabwe
P. O. Box A 178, Avondale
Harare

RE: PERMISSION TO CARRY OUT RESEARCH IN SOME SELECTED SCHOOLS - In Harare Province: St Georges College, Eaglesvale, Prince Edward, Churchill, Hellenics, Gateway and St Johns High Schools; on the research title: "School Clinical Rugby measure (SCRum): What Makes or Breaks A Good Adolescent Rugby player"

Reference is made to your letter dated 19 January 2016

Please be advised that the Provincial Education Director grants you authority to carry out your research on the above topic. You are required to supply Provincial Office with a copy of your research findings.

Signature Removed

MINISTRY OF EDUCATION
HARARE REGION
0 1 FEB 2016
BOX CY 1343, CAUSEWAY
ZIMBABWE

For: Provincial Education Director
Harare Metropolitan Province

5

Appendix Y: Letter of approval from the headmaster of the selected school

Mr Tawanda Jimu

The Headmaster

Prince Edward School

P.O Box CY 418, Causeway

Harare

Signature Removed

Date: 08 March 2016

Dear Sir/Madam

RE: APPLICATION FOR PERMISSION TO CARRY OUT RESEARCH AT YOUR SCHOOL

I would like to apply for permission to conduct a research study at your school. My name is Matthew Chiwaridzo. I am physiotherapist by profession and currently am working as a physiotherapy lecturer at the University of Zimbabwe, Faculty of Medicine in the Department of Rehabilitation. I am currently enrolled as a post graduate student pursuing my Doctor of Philosophy Degree (PhD) in the field of Sports Physiotherapy at the University of Cape Town in South Africa. As part of my studies, I am expected to conduct a research study. My research topic reads **"SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"**. I do hereby request for your permission to include your school in this study.

It is anticipated that the results of this study will be of immense significance in developing and monitoring talented young adolescent rugby players in the country. Additionally, the results of this study will inform the local and national rugby coaches on the key physiological variables and game specific skills that are crucial in the sport of rugby in light of injury prevention.

The study intends to include high schools in Harare participating mainly in the Super 8 and the Co-educational High School Rugby League. These schools represent the best rugby schools in the country. I intend to share my results of this study with your school, Zimbabwe Rugby Union, and the Ministry of Primary and Secondary Schools upon successful completion of my studies. I would be grateful if you allow me to conduct this project at your school.

I am looking forward to hearing from you.

Yours faithfully

Signature Removed

Matthew Chiwaridzo

Cell: 0773 603 069

Tel: 04-791631 Ext 2175

Email: matthewchiwaridzo@yahoo.co.uk

Appendix Z: Information letter and assent form for participating students

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Dear student,

My name is Matthew Chiwaridzo. I am a registered physiotherapist currently employed by the University of Zimbabwe as a physiotherapy lecturer. I am pursuing my higher degree (PhD) studies at the University of Cape Town in South Africa. As part of the degree, I am conducting a research project entitled: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***. My research team includes my supervisors: Professor Bouwien Smits-Engelsman and Dr Gillian Ferguson from UCT, and research assistants from the University of Maastricht in the Netherlands and from the University of Zimbabwe. I would like to invite you to participate in my research study. To help you make an informed decision regarding your participation in this study, I have prepared some information for you below.

PURPOSE OF THE STUDY

The whole research project is running in three linked phases. I am inviting you to participate in the part called the "reliability" study. So far, we have managed to develop a test battery called the SCRuM and we have recently asked the local school rugby coaches to rate the practicality, relevance and simplicity of the tests in the SCRuM. Now, I would say we have a new version of the SCRuM which has been proven feasible by your coaches. But we now want to establish if the tests in the SCRuM are reliable in our local context.

WHY HAVE I CONTACTED YOU?

I have contacted you because you are playing rugby at school. For this study we were specifically looking for state schools competing in the Super Eight Schools Rugby league. You happen to be in one of those schools. The final lists of schools selected for this study were randomly selected and no preferential selection or favouritism was done. In the schools, we were specifically targeting male adolescent rugby players playing for the first or second rugby school team, as these players represent the elite rugby players. You happen to be in the school team. Participating in this study is your choice and you are allowed to take your time to go through the information letter and make an informed decision later.

WHAT WILL YOU BE ASKED TO DO?

Initially, you will be asked to complete a questionnaire called the Physical Activity Readiness Questionnaire (PAR-Q) just to check if you don't have any medical condition that need to be considered before they participate in some physical activity. Students with a recent medical history that precludes them from physical activity will be excluded from the study since the study involved tests that may require physical exertion. The questionnaire will take 10 minutes of your time and will be completed during your free time. Secondly, you will undergo a battery of tests. The measurements will be conducted by the researcher and his team of assistants in your school after class. This to ensure there is no disruption of your lessons. The entire study will take about two weeks and is expected to start in the second school term.

ARE THERE RISKS INVOLVED?

There are minimal risks involved with the study but are not beyond what you experiences ordinarily while playing the sport of rugby at school or home. However, one major concern is the extensive number of tests to be performed. The SCRuM was designed to include all the tests of all the important qualities and skills needed in rugby. For this purpose, the research team will plan around avoiding the performance of all the tests in a single session. The SCRuM tests will be divided into three based on simplicity of executing the test: simple, moderately simple and difficult tests. The testing will be staggered and the research team will make an effort to synchronise the tests with the planned activities by coaches during training. It is expected to feel fatigue or tiredness especially when performing physically demanding tests for endurance. The research team will avoid that by minimising the number of trials to be recorded for each individual and allowing period of sufficient rest between tests. Water will be made available should you need something to drink and a light snack (fruit) will be available to boost energy during or after the session. Any complaint of pain or discomfort will be accommodated and you only be allowed to continue when they feel better.

In addition, during the testing there is a possibility of accidental injuries that may occur from falling while running or sprinting. Although most of these accidental injuries are unavoidable, the research team will make sure that you fully comprehend the instructions of the tests to be performed and we will allow you to have at least one practice trial of the test before the execution of the test trial. You will also be encouraged to do a brief warm-up exercise prior to the test trial. The researchers will also have a first aid kit in case need arises. If you become seriously ill or seriously injured, the school authorities and parents will be notified immediately and all support such as transport will be organised by the research team. All the researchers are considered adequately trained to identify situations in which referral for medical or psychological services are indicated. As far as psychological harm is concerned, it may be disconcerting for you have the measurements taken with peers watching. Measurements will be conducted in the absence of peers and the results will not be publicised or shouted.

UCT No-Fault Insurance Policy:

If you experiences a deterioration in your health or well-being due to unforeseen sensitivity related to participation in the study, medical care will be provided immediately by the University of Cape Town. According to the Association of the British Pharmaceutical Industry 1991, UCT will compensate without having to prove it is the university's fault. A trial-related injury is defined as one caused by activities related to our study. If an injury or abnormal side-effects does occur, one of the researchers must be notified immediately. UCT reserves the right to not provide compensation for participants who become injured as a result of not following the instructions given to them whilst taking part in the study however you still have the right to lawfully claim compensation for any injuries where you prove negligence was not the cause of the injury. Copies of these guidelines are available on request.

WHAT WILL YOU GET IF YOU TAKE PART?

There is no payment/reward for taking part in the study. We hope that the information gathered will help us in knowing if the SCRuM can be reliably used by the local rugby coaches in school. The indirect benefit to you is that you can be trained on the qualities and skills in the SCRuM and be evaluated for proficiency based on the SCRuM tests.

IS PARTICIPATION VOLUNTARY?

Participation in the study is entirely voluntary. You are not under an obligation to participate. Your refusal to participate will be respected and no repercussions will follow you and there is no need to provide an explanation for the refusal. You are not obliged to remain in the study throughout. You can withdraw at any point without consequences or the need to provide an explanation.

WILL PEOPLE KNOW WHAT ANSWERS I HAVE GIVEN?

No one will know the SCRuM test scores you get except the researchers. All the information obtained and recorded on the data collection sheet will be used specifically for this study. To ensure the confidentiality, the SCRuM measurements will be done privately with no peers watching and the PAR-Q will be completed privately as well. Your details, name or school name will not be given to anyone and will not be listed anywhere. Returned questionnaires and the SCRuM data collection sheets will be handled as sensitive material by the research team and will be handled with due care. They will be kept in the principal investigator office at the University of Zimbabwe, College of Health Sciences at Parirenyatwa hospital in the Department of Rehabilitation in a locked cupboard for the period of the whole study. The hard copies will be destroyed after two years following a release of a published article which utilise that data. However, the results of this project will be made available to you at the end of this part of the study and to your school at the end of the PhD project and to the global audience through publications that will emerge from the project but will not be linked to you in any way.

IS THE STUDY APPROVED?

I have been given ethical approval by Human Research Ethics Committee in South Africa and the Medical Research Council of Zimbabwe to conduct the study. These committees make sure that you are protected. I have provided contact details for these ethical committees at the end of this information letter in case you want to verify the details of this study. I have also obtained institutional approval from the Ministry of Primary and Secondary Education and from your school headmaster to conduct the study at your school.

WHO TO CONTACT FOR MORE INFORMATION?

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. For more queries, you may contact the Faculty of Health Sciences, Human Research Ethics Committee (+27 21 406 6338) through their chairman, Professor Marc Blockman for any questions or concerns regarding your rights or welfare as a participant in this study. Locally, you contact the Registrar at the Medical Research Council of

Zimbabwe on the following numbers +263 4 791792. Should you have any questions regarding the study, you may contact the principal investigator (Matthew Chiwaridzo) on the following number +263 773 603 069 or through email at matthewchiwaridzo@yahoo.co.uk. My physical address is **University of Zimbabwe, College of Health Sciences, Rehabilitation Department, Room 41, Ground Floor, New Health Sciences Building, P.O Box A178 Avondale, Harare, Zimbabwe**. You may also contact my supervisor, Professor Bouwien Engelsman on bouwiensmits@hotmail.com. Additionally, contact my co-supervisor from the University of Cape Town, Dr Gillian Ferguson at this email address, gillian.ferguson@uct.ac.za or at the following physical address as well, **Division of Physiotherapy Department of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town**, Tel: + 27 21 406 6045.

Your cooperation is greatly appreciated. If you chose to allow your child to participate, please sign the attached informed consent form.

Yours faithfully,

Matthew Chiwaridzo

University of Cape Town PhD Student

Signature………………………………………..

Date…………………………………………………..

Student Assent form

	School of Health and Rehabilitation Sciences **Faculty of Health Sciences** Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

Study title: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player***".

Institution: University of Cape Town, Faculty of Health Sciences, Division of Physiotherapy

I -- hereby confirm that I have read the information sheet given to me by the researcher, Matthew Chiwaridzo. I have received enough information about the nature and the purpose of the research project to be conducted at my school. I completely understand what is required of me and I have had all my questions answered. I am aware that all the results and information including personal details will be strictly confidential and will remain anonymous in all reports relating to the study. I do not feel that I being forced to take part in this study. I know that I can withdraw at any time if I so wishes and that it will have no bad consequences for me.

Signed:

-- ---

Participant date and place

--- ---

Researcher date and place

--- ---

Witness date and place

Appendix AA: Adolescent Medical Health Questionnaire

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

TO BE COMPLETED BY THE PARENT OR GUARDIAN

Participant Reference Number…………………….....   Date……………

Instructions: *Please indicate with a tick in the appropriate box. We require you to answer this questionnaire truthfully and honestly. The information you provide is important to decide whether your child will be included in the study or not. When completed, please return the questionnaire in a provided stamped envelope to the following physical address addressed to Matthew Chiwaridzo:* **University of Zimbabwe, College of Health Sciences, Rehabilitation Department, P.O Box A178, Avondale, Harare**. *You may also want to send the questionnaire in a sealed envelope with your child to their school form teacher or school rugby coach. The researcher will collect it from there.*

1. What is your relation to the child? ....
2. Are you aware that your child plays rugby for his school team?
   Yes ☐ No ☐
3. Is your child currently or in the last few weeks in good health?
   Yes ☐ No ☐
   If you answered **no**, please give further details
   ……………………………..
4. During the past **six** weeks, has your child sustained a head or musculoskeletal injury that you are aware of which may affect his performance in physical activity?
   Yes ☐ No ☐
5. Has your child been diagnosed by a doctor or another health professional in the past six weeks with any condition that affect his hips, back, knee and ankles?
   Yes ☐ No ☐
6. Does your child have at this present time hip, knee, back and ankle pain because of a recent musculoskeletal injury diagnosed?
   Yes ☐ No ☐
7. Does your child have any pain that could be aggravated by physical activity?
   Yes ☐ No ☐
8. Is your child currently following a specialised treatment programme with a medical doctor for any specific reason?

Yes ☐ No ☐
If yes, please can specify what medication he is getting...

9. Is your child currently following a rehabilitation programme for any reason?
Yes ☐ No ☐
If yes, please specify what rehabilitation treatment is he getting………………………………

10. Has your child been bothered by any of the following problems in the last six weeks?

Problem	**Yes**	**No**
Diabetes		
Dizziness		
Heart problems		
Blood pressure problems		
Asthma, chronic bronchitis or shortness of breath		
Epilepsy or fainting attacks		
Migraine		
Severe headaches		
Back pain problems		
Physical disability or other		
Recent fracture		
Chest pain		
Hip, knee or ankle pain		
Psychiatric or mental problem		

11. Has any doctor ever said that you child has a heart condition and that he should only perform physical activity recommended by a doctor?
Yes ☐ No ☐

12. Does your child complain of pain in the chest when they perform physical activity or not?
Yes ☐ No ☐

13. Does your child lose balance because of dizziness or do they ever lose consciousness?
Yes ☐ No ☐

14. Does your child have a bone or joint problem that could be made worse by physical activity?
Yes ☐ No ☐
15. Is your child currently taking prescribed medication for blood pressure or for a heart condition?
Yes ☐ No ☐

16. Do you know of any other reason why your child should not engage in physical activity? ....…......................

Appendix AB: Parental/guardian information letter and consent form

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Dear Parent/guardian

My name is Matthew Chiwaridzo. I am a qualified physiotherapist currently employed by the University of Zimbabwe as a physiotherapy lecturer. I am pursuing my higher degree (PhD) studies at the University of Cape Town in South Africa. As part of the degree, I am conducting a research project entitled: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***. My research team includes my supervisors: Prof Bouwien Smits-Engelsman and Dr Gillian Ferguson from UCT, and research assistants from the University of Maastricht in the Netherlands and from the University of Zimbabwe. I would like to invite you child to participate in my research study. To help you make an informed decision regarding your child's participation in this study, I have prepared some information for you below.

PURPOSE OF THE STUDY

The whole research project is running in three linked phases. I am inviting your child to participate in the study called the "reliability" study. So far, we have managed to develop a test battery called the SCRuM and we have recently asked the local school rugby coaches about the practicality, relevance and simplicity of the tests in the SCRuM. Now, we want to test if the newly-developed SCRuM that has been found to be feasible whether it is reliable among high school male adolescent rugby players.

WHY HAVE I CONTACTED YOU?

I have contacted you because you have a child playing competitive high school rugby at a state school competing in the Super Eight Schools Rugby League. Your child's school happens to be one of them. Selection of the schools was random and no preferential selection or favouritism was done. In the schools, we were specifically targeting male adolescent rugby players playing for the first or second rugby school team, as these players represent the elite rugby players. Your child happens to be in the school team and because of that he is eligible but not obligated to participate in the study. The decision to participate lies squarely with him and he will not be coerced or forced to participate outside his will. The research team will be looking for students who volunteer on their own to participate in the study and having your permission as well.

WHAT WILL YOU CHILD BE ASKED TO DO?

Initially, your child will be asked to complete a questionnaire called the Physical Activity Readiness Questionnaire (PAR-Q) to assess for any medical condition that need to be considered before they participate in some physical activity. Adolescents with a medical history that precludes them from physical activity will be excluded from the study since the study involved tests that may require physical exertion. This questionnaire (PAR-Q) has been attached with this letter for you to see some of the questions they will be asked. The questionnaire will take 10 minutes of their time and will be completed by students at school during their free time. Secondly, included students will undergo a battery of tests which have been found to be safe, feasible and easy to perform by their local coaches. The measurements will be conducted by the researcher and his team of assistants in the schools after school lessons. This to ensure there is no disruption of their lessons. The entire study will take about two weeks and is expected to start in the second school term.

ARE THERE RISKS INVOLVED?

There are minimal risks involved with the study which are not beyond what the child experiences ordinarily while playing the sport of rugby at school or home. However, one major concern is the extensive number of tests to be performed. The SCRuM was designed to include all the tests of all the important qualities and skills needed in rugby. Hence, it is rigorous. For this purpose, the research team will plan around avoiding the performance of all the tests in a single session. The SCRuM tests will be divided into three based on simplicity of executing the test: simple, moderately simple and difficult tests. The testing of the participants will be staggered and the research team will make an effort to synchronise the tests with the planned activities by coaches during training. It is better for physical tests of speed to be conducted when the participants are training in the field and the upper body strength measures to be conducted during their gym based training days. The research team will conduct the tests incrementally starting with simple tests going towards the harder ones.

Performance of the physically demanding tests such as the multistage shuttle run for endurance may result in participants feeling fatigued or having muscle soreness after the tests. The research team will avoid that by minimising the number of trials to be recorded for each individual and allowing period of sufficient rest between tests. Water will be made available should the participants need something to drink and an apple will be available to boost energy during or after the session. Any complaint of pain or discomfort will be accommodated and the participant will only be allowed to continue when they feel better.

In addition, during the testing there is a possibility of accidental injuries that participants need to be warned off resulting from falling while running or sprinting. Although most of these accidental injuries are unavoidable, the research team will make sure that the participants fully comprehend the instructions of the tests to be performed and allow the participants to have at least one practice trial of the test before the execution of the test trial. The participants will also be encouraged to do a brief warm up exercise prior to the test trial. In some instances, the researchers will have to stand close to the participant to minimise the risk of falling for example when performing balance activities.

The researchers will also have a first aid kit in case need arises. If the participants become seriously ill or seriously injured, the school authorities and parents will be notified immediately and all support such as transport will be organised by the research team. All the researchers are considered adequately trained to identify situations in which referral for medical are indicated. As far as emotional or psychological harm is concerned, SCRuM tests measurements will be conducted in the absence of other peers and the results will not be publicised or shouted.

WHAT WILL YOUR CHILD GET IF THEY TAKE PART?

There is no payment/reward for taking part in the study. We hope that the information gathered will help us in knowing if the SCRuM can be reliably used by the local rugby coaches in school. The indirect benefit for your child is that they can be trained on the qualities and skills in the SCRuM and be evaluated for proficiency based on the SCRuM tests.

IS PARTICIPATION VOLUNTARY?

Participation in the study is entirely voluntary. Your child is not under an obligation to participate. Your refusal to allow your child to participate will be respected and no repercussions will follow you or your child and there is no need to provide an explanation for the refusal. Your child has no obligation to remain in the study and can withdraw at any point without consequences or the need to provide an explanation.

WILL PEOPLE KNOW WHAT ANSWERS I HAVE GIVEN?

No one will know the SCRuM test scores your child get during the measurements except the researchers. All the information obtained and recorded on the data collection sheet will be used specifically for this study. To ensure the confidentiality of your child, the SCRuM measurements will be done privately without any peers watching and the PAR-Q will be completed privately as well. Your child's details, name or school name will not be given to anyone and will not be listed anywhere. Returned questionnaires and the SCRuM data collection sheets will be handled as sensitive material by the research team and will be handled with due care. They will be kept in the principal investigator office at the University of Zimbabwe, College of Health Sciences at Parirenyatwa hospital in the Department of Rehabilitation in a locked cupboard for the period of the whole study. The hard copies will be destroyed after two years following a release of a published article which utilise that data. However, the results of this project will be made available to the schools that participate and the global audience through publication but will not be linked to your child in any way.

IS THE STUDY APPROVED?

I have been given ethical approval by Human Research Ethics Committee in South Africa and the Medical Research Council of Zimbabwe to conduct the study. These committees make sure that your child is protected. I have provided contact details for these ethical committees at the end of this information letter in case you want to verify the details of this study. I have also obtained institutional approval from the Ministry of Primary and Secondary Education and from your child's school headmaster to conduct the study at his/her school.

UCT No-Fault Insurance Policy

If you child experiences a deterioration in his health or well-being due to unforeseen sensitivity related to participation in the study, medical care will be provided immediately by the University of Cape Town. According to the Association of the British Pharmaceutical Industry 1991, UCT will compensate without having to prove it is the university's fault. A trial-related injury is defined as one caused by activities related to our study. If an injury or abnormal side-effects does occur, one of the researchers must be notified immediately. UCT reserves the right to not provide compensation for participants who become injured as a result of not following the instructions given to them whilst taking part in the study however you still have the right to lawfully claim compensation for any injuries where you prove negligence was not the cause of the injury. Copies of these guidelines are available on request.

WHO TO CONTACT FOR MORE INFORMATION?

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. For more queries, you may contact the Faculty of Health Sciences, Human Research Ethics Committee (+27 21 406 6338) through their chairman, Professor Marc Blockman for any questions or concerns regarding your rights or welfare as a participant in this study. Locally, you contact the Registrar at the Medical Research Council of Zimbabwe on the following numbers +263 4 791792. Should you have any questions regarding the study, you may contact the principal investigator (Matthew Chiwaridzo) on the following number +263 773 603 069 or through email at matthewchiwaridzo@yahoo.co.uk. My physical address is **University of Zimbabwe, College of Health Sciences, Rehabilitation Department, Room 41, Ground Floor, New Health Sciences Building, P.O Box A178 Avondale, Harare, Zimbabwe**. You may also contact my supervisor, Professor Bouwien Engelsman on bouwiensmits@hotmail.com. Additionally, contact my co-supervisor from the University of Cape Town, Dr Gillian Ferguson at this email address, gillian.ferguson@uct.ac.za or at the following physical address as well, **Division of Physiotherapy Department of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town**, Tel: +27 21 406 6045

Your cooperation is greatly appreciated. If you chose to allow your child to participate, please sign the attached informed consent form.

Yours faithfully,

Matthew Chiwaridzo

University of Cape Town PhD Student

Signature………………………………………..

Date…………………………………………………..

Informed consent form

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Study title: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player***".

Institution: University of Cape Town

I -- hereby confirm that I have read the information sheet given to me by the researcher, Matthew Chiwaridzo. I have received enough information about the nature and the purpose of the research project to be conducted at my child's school. I completely understand what is required of my child and I have had all my questions answered. I am aware that all the results and information including personal details of my child will be strictly confidential and will remain anonymous in all reports relating to the study. I do not feel that my child is being forced to take part in this study and I am giving him the permission to participate if he so desires. I know that my child can withdraw at any time if he so wishes and that it will have no bad consequences for me or him. I have also completed the attached Adolescent Medical Health Questionnaire which the researcher will use to determine if my child meets the inclusion criteria of the study.

Signed:

--- ---

Participant date and place

--- ---

Researcher date and place

--- ---

Witness date and place

Appendix AC: Physical Activity Readiness Questionnaire

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Section A: Demographic data

Reference number……………………………………………………

Date………………………………….. Age: __________

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Questions	Yes	No
1. Has your doctor ever said that you have a heart condition and that you should only perform physical activity recommended by a doctor?		
2. Do you feel pain in your chest when you perform physical activity?		
3. In the past month, have you had chest pain when you were not performing any physical activity?		
4. Do you lose balance because of dizziness or do you ever lose consciousness?		
5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?		
6. Is your doctor currently prescribing any medication for your blood pressure or for a heart condition?		
7. Do you know of any other reason why you should not engage in physical activity?		

If you have answered "Yes" to one or more of the above questions, consult your physician before engaging in physical activity. Tell your physician which questions you answered "Yes" to. After a medical evaluation, seek advice from your physician on what type of activity is suitable for your current condition.

GENERAL AND MEDICAL QUESTIONNAIRE

Occupational Questions	**Yes**	**No**
8. What is your current occupation? ____		
9. Does your occupation require extended periods of sitting?		
10. Does your occupation require extended periods of repetitive movements? (If yes, please explain.)____		
11. Does your occupation require you to wear shoes with a heel (dress shoes)?		
12. Does your occupation cause you anxiety (mental stress)?		
Recreational Questions		
13. Do you partake in any recreational activities (golf, tennis, skiing, etc.)? (If yes, please explain.)____		
14. Do you have any hobbies (reading, gardening, working on cars, exploring the Internet, etc.)? (If yes, please explain.) ____		

Medical Questions		
15. Have you ever had any pain or injuries (ankle, knee, hip, back, shoulder, etc.)? (If yes, please explain.) ____ ____		
16. Have you ever had any surgeries? (If yes, please explain.) ____		
17. Has a medical doctor ever diagnosed you with a chronic disease, such as Coronary heart disease, coronary artery disease, hypertension (high blood pressure), high cholesterol or diabetes? (If yes, please explain.) ____ ____		
18. Are you currently taking any medication? (If yes, please list.) ____ ____ ____		

Appendix AD: Letter of approval from the headmaster of the selected school

The Headmaster

Churchill Boys High School

P.O Box CY 616, Causeway

Harare

Date: 08 March 2016

Dear Sir

RE: APPLICATION FOR PERMISSION TO CARRY OUT RESEARCH AT YOUR SCHOOL

I would like to apply for permission to conduct a research study at your school. My name is Matthew Chiwaridzo. I am physiotherapist by profession and currently am working as a physiotherapy lecturer at the University of Zimbabwe, Faculty of Medicine in the Department of Rehabilitation. I am currently enrolled as a post graduate student pursuing my Doctor of Philosophy Degree (PhD) in the field of Sports Physiotherapy at the University of Cape Town in South Africa. As part of my studies, I am expected to conduct a research study. My research topic reads "**SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player**". I do hereby request for your permission to include your school in this study.

It is anticipated that the results of this study will be of immense significance in developing and monitoring talented young adolescent rugby players in the country. Additionally, the results of this study will inform the local and national rugby coaches on the key physiological variables and game specific skills that are crucial in the sport of rugby in light of injury prevention.

The study intends to include high schools in Harare participating mainly in the Super 8 and the Co-educational High School Rugby League. These schools represent the best rugby schools in the country. I intend to share my results of this study with your school, Zimbabwe Rugby Union, and the Ministry of Primary and Secondary Schools upon successful completion of my studies. I would be grateful if you allow me to conduct this project at your school.

I am looking forward to hearing from you.

Your faithfully Signature Removed

Matthew Chiwaridzo

Cell: 0773 603 069

Tel: 04-791631 Ext 2175

Email: matthewchiwaridzo@yahoo.co.uk

THE HEADMASTER
CHURCHILL SCHOOL
07 MAR 2016
P.O. BOX CY 616
CAUSEWAY, ZIMBABWE

Accepted

Appendix AE: Letter of approval from the headmaster of the selected school

6568 Granary

Snake Park

Harare

18/01/2016

Dear Sir/Madam

RE: APPLICATION FOR PERMISSION TO CARRY OUT RESEARCH IN SCHOOLS

My name is Matthew Chiwaridzo, employed as a Physiotherapy lecturer at the University of Zimbabwe, College of Health Sciences in the Department of Rehabilitation. Currently, I am post graduate student pursuing my Doctor of Philosophy Degree (PhD) in Sports Physiotherapy at the University of Cape Town (UCT) in South Africa. As part of my studies, I am expected to conduct a research project. My research topic is entitled **"SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player".** I hereby request permission to carry out the above mentioned study in high schools in Harare, Zimbabwe. I have attached with this letter proof of student confirmation from my university.

It is anticipated that the results of this study will be helpful in developing and monitoring talented young adolescent rugby players in the country. Additionally, the results of this study will inform the local and national rugby coaches on the key physiological variables and game specific skills that are crucial in the sport of rugby in light of injury prevention. This is important in developing screening instruments for selecting, monitoring young players and in injury prevention strategies. This study will include high schools in Harare, Zimbabwe including government-administered and none. High schools based particularly participating in the Super Eight Schools Rugby League will be preferentially selected because of the experience of their rugby players and by virtue of playing in the elite league.

I intend to share the outcome of this research study with the Ministry of Primary and Secondary Education on successful completion of my PhD degree. Participation of the schools will be purely voluntary and they will be randomly selected. I would be grateful if you give me permission to conduct the research study in the schools in Harare.

I am looking forward to your favourable response

Yours faithfully

Matthew Chiwaridzo

Signature Removed

Tel: 0773603069

Email: matthewchiwaridzo@yahoo.co.uk

EAGLESVALE SCHOOL
SPORTS DIRECTOR
Signature Removed
8 MAR 2016
P.O. BOX ST650
SOUTHERTON, HARARE
TEL. 664480

Appendix AF: Parent information letter and consent form for the validation study

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Dear Parent/guardian

My name is Matthew Chiwaridzo. I am a qualified physiotherapist currently employed by the University of Zimbabwe as a physiotherapy lecturer. I am pursuing my higher degree (PhD) studies at the University of Cape Town in South Africa. As part of the degree, I am conducting a research project entitled: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***. My research team includes my supervisors: Prof Bouwien Smits-Engelsman and Dr Gillian Ferguson from UCT, and research assistants from the University of Maastricht in the Netherlands and from the University of Zimbabwe. I would like to invite you child to participate in my research study. To help you make an informed decision regarding your child's participation in this study, I have prepared some information for you below.

PURPOSE OF THE STUDY

The whole research project is running in three linked phases. I am inviting your child to participate in the last part of the project called the "validation" study. So far, we have managed to develop a test battery called the SCRuM and we have recently tested for its reliability in male adolescent rugby players. Now, we want to test to see if it can discriminate between good and not so good rugby players among high school male adolescent rugby players by comparing male adolescent athletes playing elite, sub-elite and non-rugby players playing the sport of cricket.

WHY HAVE I CONTACTED YOU?

I have contacted you because you have a child playing high school rugby or cricket at a private school. For this study we were specifically looking for schools competing in the two domestic high school rugby leagues and schools known for playing good cricket. Your child's school happens to be one of them. The final list of schools selected for this study was randomly selected and no preferential selection or favouritism was done. In the schools, we were specifically targeting male adolescent rugby or cricket players playing for the U16 and U19 school teams. Your child happens to be in the school team and hence he is eligible to participate in the study. However, the decision to participate lies squarely with him and he will not be coerced or forced to participate outside his will.

WHAT WILL YOU CHILD BE ASKED TO DO?

Initially, your child will be asked to complete a questionnaire called the Physical Activity Readiness Questionnaire (PAR-Q) just to check if they do or don't have any medical condition that need to be considered before they participate in some physical activity. Adolescents with a medical history that precludes them from physical activity will be excluded from the study since the study involved tests that may require physical exertion. This questionnaire (PAR-Q) has been attached with this letter for you to see some of the questions they will be asked. The questionnaire will take 10 minutes of their time and will be completed by students at school during their free time. Secondly, included students will undergo a battery of tests which have been found to be safe, feasible and easy to perform by their local coaches. The measurements will be conducted by the researcher and his team of assistants in the schools after the school. This to ensure there is no disruption of their lessons. The entire study will take about two weeks and is expected to start in the second school term.

ARE THERE RISKS INVOLVED?

There are minimal risks involved with the study which are not beyond what the child experiences ordinarily while playing the sport of rugby or cricket at school or home. However, one major concern is the extensive number of tests to be performed. The SCRuM was designed to include all the tests of all the important qualities and skills needed in rugby. Hence, it is rigorous. For this purpose, the research team will plan around avoiding the performance of all the tests in a single session. The SCRuM tests will be divided into three based on simplicity of executing the test: simple, moderately simple and difficult tests. The testing of the participants will be staggered and the research team will make an effort to synchronise the tests with the planned activities by coaches during training. It is better for physical tests of speed to be conducted when the participants are training in the field and the upper body strength measures to be conducted during their gym based training days. The research team will conduct the tests incrementally starting with simple tests going towards the harder ones.

Performance of the physically demanding hard tests such as the multistage shuttle run for anaerobic endurance may result in participants feeling fatigued or having delayed onset muscle soreness after the tests. The research team avoid that by minimising the number of trials to be recorded for each individual and allowing period of sufficient rest between tests. Water will be made available should the participants need something to drink and an apple will be available to boost energy during or after the session. Any complaint of pain or discomfort will be accommodated and the participant will only be allowed to continue when they feel better. In addition, during the testing there is a possibility of accidental injuries that participants need to be warned off resulting from falling while running or sprinting. Although most of these accidental injuries are unavoidable, the research team will make sure that the participants fully comprehend the instructions of the tests to be performed and allow the participants to have at least one practice trial of the test before the execution of the test trial. The participants will also be encouraged to do a brief warm up exercise prior to the test trial. In some instances, the researchers will have to stand close to the participant to minimise the risk of falling for example when performing balance activities.

The researchers will also have a first aid kit in case need arises. If the participants become seriously ill or seriously injured, the school authorities and parents will be notified immediately and all support such as transport will be organised by the research team. All the researchers are considered adequately trained to identify situations in which referral for medical or psychological services are indicated. As far as psychological harm is concerned, it may be disconcerting to participants that they are not performing with their peers watching. Measurements will be conducted in the absence of peers and the results will not be publicised or shouted.

UCT No-Fault Insurance Policy:

If you child experiences a deterioration in his health or well-being due to unforeseen sensitivity related to participation in the study, medical care will be provided immediately by the university of Cape Town. According to the Association of the British Pharmaceutical Industry 1991, UCT will compensate without having to prove it is the university's fault. A trial-related injury is defined as one caused by activities related to our study. If an injury or abnormal side-effects does occur, one of the researchers must be notified immediately. UCT reserves the right to not provide compensation for participants who become injured as a result of not following the instructions given to them whilst taking part in the study however you still have the right to lawfully claim compensation for any injuries where you prove negligence was not the cause of the injury. Copies of these guidelines are available on request.

WHAT WILL YOUR CHILD GET IF THEY TAKE PART?

There is no payment/reward for taking part in the study. We hope that the information gathered will help us in knowing if the SCRuM can be used by the local rugby coaches in school to screen for good players. The indirect benefit for your child is that they can be trained on the qualities and skills in the SCRuM and be evaluated for proficiency based on the SCRuM tests.

IS PARTICIPATION VOLUNTARY?

Participation in the study is entirely voluntary. Your child is not under an obligation to participate. Your refusal to allow your child to participate will be respected and no repercussions will follow you or your child and there is no need to provide an explanation for the refusal. Your child has no obligation to remain in the study and can withdraw at any point without consequences or the need to provide an explanation.

WILL PEOPLE KNOW WHAT ANSWERS I HAVE GIVEN?

No one will know the SCRuM test scores your child get during the measurements except the researchers. All the information obtained and recorded on the data collection sheet will be used specifically for this study. To ensure the confidentiality of your child, the SCRuM measurements will be done privately without any peers watching and the PAR-Q will be completed privately as well. Your child's details, name or school name will not be given to anyone and will not be listed anywhere. Returned questionnaires and the SCRuM data collection sheets will be handled as sensitive material by the research team and will be handled with due care. They will be kept in the principal investigator office at the University of Zimbabwe, College of Health Sciences at Parirenyatwa hospital in the Department of Rehabilitation in a locked cupboard for the period of the whole study. The hard copies will be destroyed after two years following a release of a published article which utilise that data. However, the results of this project will be made available to the schools that participate and the global audience through publication but will not be linked to your child in any way.

IS THE STUDY APPROVED?

I have been given ethical approval by Human Research Ethics Committee in South Africa and the Medical Research Council of Zimbabwe to conduct the study. These committees make sure that your child is protected. I have provided contact details for these ethical committees at the end of this information letter in case you want to verify the details of this study. I have also obtained institutional approval from the Ministry of Primary and Secondary Education and from your child's school headmaster to conduct the study at his/her school.

WHO TO CONTACT FOR MORE INFORMATION?

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. For more queries, you may contact the Faculty of Health Sciences, Human Research Ethics Committee (+27 21 406 6338) through their chairman, Professor Marc Blockman for any questions or concerns regarding your rights or welfare as a participant in this study. Locally, you contact the Registrar at the Medical Research Council of Zimbabwe on the following numbers +263 4 791792. Should you have any questions regarding the study, you may contact the principal investigator (Matthew Chiwaridzo) on the following number +263 773 603 069 or through email at matthewchiwaridzo@yahoo.co.uk. My physical address is **University of Zimbabwe, College of Health Sciences, Rehabilitation Department, Room 41, Ground Floor, New Health Sciences Building, P.O Box A178 Avondale, Harare, Zimbabwe**. You may also contact my supervisor, Professor Bouwien Engelsman on bouwiensmits@hotmail.com. Additionally, contact my co-supervisor from the University of Cape Town, Dr Gillian Ferguson at this email address, gillian.ferguson@uct.ac.za or at the following physical address as well, **Division of Physiotherapy Department of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town**, Tel: + 27 21 406 6045.

Your cooperation is greatly appreciated. If you chose to allow your child to participate, please sign the attached informed consent form.

Yours faithfully,

Matthew Chiwaridzo

University of Cape Town PhD Student

Signature………………………………………..Date……………………………………….

Informed consent form

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Study title: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player***".

Institution: University of Cape Town, Faculty of Health Sciences, Division of Physiotherapy

I -- hereby confirm that I have read the information sheet given to me by the researcher, Matthew Chiwaridzo. I have received enough information about the nature and the purpose of the research project to be conducted at my child's school. I completely understand what is required of my child and I have had all my questions answered. I am aware that all the results and information including personal details of my child will be strictly confidential and will remain anonymous in all reports relating to the study. I do not feel that my child is being forced to take part in this study and I am giving him the permission to participate if he so desires. I know that my child can withdraw at any time if he so wishes and that it will have no bad consequences for me or him. I have also completed the attached Adolescent Medical Health Questionnaire which the researcher will use to determine if my child meets the inclusion criteria of the study.

Signed:

--	---
Participant	date and place
--	---
Researcher	date and place
---	---
Witness	date and place

Appendix AG: Information sheet and students assent form for validation study

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Dear student,

My name is Matthew Chiwaridzo. I am a registered physiotherapist currently employed by the University of Zimbabwe as a physiotherapy lecturer. I am pursuing my higher degree (PhD) studies at the University of Cape Town in South Africa. As part of the degree, I am conducting a research project entitled: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***. My research team includes my supervisors: Professor Bouwien Smits-Engelsman and Dr Gillian Ferguson from UCT, and research assistants from the University of Maastricht in the Netherlands and from the University of Zimbabwe. I would like to invite you to participate in my research study. To help you make an informed decision regarding your participation in this study, I have prepared some information for you below.

PURPOSE OF THE STUDY

The whole research project is running in three linked phases. I am inviting you to participate in the last part of the project called the "validation" study. So far, we have managed to develop a test battery called the SCRuM and we have recently tested its reliability among male adolescent rugby players. Now, I would say we have a new version of the SCRuM which has been proven feasible by your coaches with established reliability. But we now want to establish if the SCRuM can discriminate between good and not so good players.

WHY HAVE I CONTACTED YOU?

I have contacted you because you are playing rugby or cricket at school. For this study we were specifically looking for private schools competing in the two domestic high school rugby leagues and schools known for playing good cricket. You happen to be in one of those schools. The final lists of schools selected for this study were randomly selected and no preferential selection or favouritism was done. In the schools, we were specifically targeting male adolescent rugby players playing for the U16 and U19 rugby or cricket school team. You happen to be in the school team.

WHAT WILL YOU BE ASKED TO DO?

Initially, you will be asked to complete a questionnaire called the Physical Activity Readiness Questionnaire (PAR-Q) just to check if you don't have any medical condition that need to be considered before they participate in some physical activity. Students with a recent medical history that precludes them from physical activity will be excluded from the study since the study involved tests that may require physical exertion. The questionnaire will take 10 minutes of your time and will be completed during your free time. Secondly, you will undergo a battery of tests. The measurements will be conducted by the researcher and his team of assistants in your school after class. This to ensure there is no disruption of your lessons. The entire study will take about two weeks and is expected to start in the second school term.

ARE THERE RISKS INVOLVED?

There are minimal risks involved with the study but are not beyond what you experiences ordinarily while playing the sport of rugby or cricket at school or home. However, one major concern is the extensive number of tests to be performed. The SCRuM was designed to include all the tests of all the important qualities and skills needed in rugby. For this purpose, the research team will plan around avoiding the performance of all the tests in a single session. The SCRuM tests will be divided into three based on simplicity of executing the test: simple, moderately simple and difficult tests. The testing will be staggered and the research team will make an effort to synchronise the tests with the planned activities by coaches during training. It is expected to feel fatigue or tiredness especially when performing physically demanding tests for endurance. The research team will avoid that by minimising the number of trials to be recorded for each individual and allowing period of sufficient rest between tests. Water will be made available should you need something to drink and a light snack (fruit) will be available to boost energy during or after the session. Any complaint of pain or discomfort will be accommodated and you only be allowed to continue when they feel better.

In addition, during the testing there is a possibility of accidental injuries that may occur from falling while running or sprinting. Although most of these accidental injuries are unavoidable, the research team will make sure that you fully comprehend the instructions of the tests to be performed and we will allow you to have at least one practice trial of the test before the execution of the test trial. You will also be encouraged to do a brief warm up exercise prior to the test trial. In some instances, the researchers will have to stand close to the participant to minimise the risk of falling for example when performing balance activities.

The researchers will also have a first aid kit in case need arises. If you become seriously ill or seriously injured, the school authorities and parents will be notified immediately and all support such as transport will be organised by the research team. All the researchers are considered adequately trained to identify situations in which referral for medical or psychological services are indicated. As far as psychological harm is concerned, it may be disconcerting for you have the measurements taken with peers watching. Measurements will be conducted in the absence of peers and the results will not be publicised or shouted.

UCT No-Fault Insurance Policy:

If you experiences a deterioration in your health or well-being due to unforeseen sensitivity related to participation in the study, medical care will be provided immediately by the university of Cape Town. According to the Association of the British Pharmaceutical Industry 1991, UCT will compensate without having to prove it is the university's fault. A trial-related injury is defined as one caused by activities related to our study. If an injury or abnormal side-effects does occur, one of the researchers must be notified immediately. UCT reserves the right to not provide compensation for participants who become injured as a result of not following the instructions given to them whilst taking part in the study however you still have the right to lawfully claim compensation for any injuries where you prove negligence was not the cause of the injury. Copies of these guidelines are available on request.

WHAT WILL YOU GET IF YOU TAKE PART?

There is no payment/reward for taking part in the study. We hope that the information gathered will help us in knowing if the SCRuM can be used in schools as way of knowing potentially good players in schools. The indirect benefit to you is that you can be trained on the qualities and skills in the SCRuM and be evaluated for proficiency based on the SCRuM tests.

IS PARTICIPATION VOLUNTARY?

Participation in the study is entirely voluntary. You are not under an obligation to participate. Your refusal to participate will be respected and no repercussions will follow you and there is no need to provide an explanation for the refusal. You are not obliged to remain in the study throughout. You can withdraw at any point without consequences or the need to provide an explanation.

WILL PEOPLE KNOW WHAT ANSWERS I HAVE GIVEN?

No one will know the SCRuM test scores you get except the researchers. All the information obtained and recorded on the data collection sheet will be used specifically for this study. To ensure the confidentiality, the SCRuM measurements will be done privately with no peers watching and the PAR-Q will be completed privately as well. Your details, name or school name will not be given to anyone and will not be listed anywhere. Returned questionnaires and the SCRuM data collection sheets will be handled as sensitive material by the research team and will be handled with due care. They will be kept in the principal investigator office at the University of Zimbabwe, College of Health Sciences at Parirenyatwa hospital in the Department of Rehabilitation in a locked cupboard for the period of the whole study. The hard copies will be destroyed after two years following a release of a published article which utilise that data. However, the results of this project will be made available to you at the end of this part of the study and to your school at the end of the PhD project and to the global audience through publications that will emerge from the project but will not be linked to you in any way.

IS THE STUDY APPROVED?

I have been given ethical approval by Human Research Ethics Committee in South Africa and the Medical Research Council of Zimbabwe to conduct the study. These committees make sure that you are protected. I have provided contact details for these ethical committees at the end of this information letter in case you want to verify the details of this study. I have also obtained institutional approval from the Ministry of Primary and Secondary Education and from your school headmaster to conduct the study at your school.

WHO TO CONTACT FOR MORE INFORMATION?

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. For more queries, you may contact the Faculty of Health Sciences, Human Research Ethics Committee (+27 21 406 6338) through their chairman, Professor Marc Blockman for any questions or concerns regarding your rights or welfare as a participant in this study. Locally, you contact the Registrar at the Medical Research Council of Zimbabwe on the following numbers +263 4 791792. Should you have any questions regarding the study, you may contact the principal investigator (Matthew Chiwaridzo) on the following number +263 773 603 069 or through email at matthewchiwaridzo@yahoo.co.uk. My physical address is **University of Zimbabwe, College of Health Sciences, Rehabilitation Department, Room 41, Ground Floor, New Health Sciences Building, P.O Box A178 Avondale, Harare, Zimbabwe**. You may also contact my supervisor, Professor Bouwien Engelsman on bouwiensmits@hotmail.com. Additionally, contact my co-supervisor from the University of Cape Town, Dr Gillian Ferguson at this email address, gillian.ferguson@uct.ac.za or at the following physical address as well, **Division of Physiotherapy Department of Health and Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town**, Tel: +27 21 406 6045.

Your cooperation is greatly appreciated. If you chose to allow your child to participate, please sign the attached informed consent form.

Yours faithfully,

Matthew Chiwaridzo

University of Cape Town PhD Student

Signature………………………………………..

Date…………………………………………….

Student assent form

School of Health and Rehabilitation Sciences

Faculty of Health Sciences

Divisions of Communications Sciences and Disorders, Disability Studies, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur Hospital,

Study title: "***SCRuM (School Clinical Rugby Measure): What makes or breaks a good adolescent rugby player"***.

Institution: University of Cape Town, Faculty of Health Sciences, Division of Physiotherapy

I -- hereby confirm that I have read the information sheet given to me by the researcher, Matthew Chiwaridzo. I have received enough information about the nature and the purpose of the research project to be conducted at my school. I completely understand what is required of me and I have had all my questions answered. I am aware that all the results and information including personal details will be strictly confidential and will remain anonymous in all reports relating to the study. I do not feel that I being forced to take part in this study. I know that I can withdraw at any time if I so wishes and that it will have no bad consequences for me.

Signed:

Participant date and place

Researcher date and place

Witness date and place

Appendix AH: Order of the testing during data collection

Group	*Week	Mon	Tues	Wedn	Thurs	Fri	Sat	Sun
E U19	Week 1	Body mass	Yo-Yo	1RM BP	Speed	RHIE	Match	Rest
		Height	2kg MBCT	WSLG	SR	Push Up		
		7 Skin folds		1RM BS	L-run			
		Sitting height		VJ				
	Week 2	Body mass	Yo-Yo	1RM BP	Speed	RHIE	Match	Rest
		Height	2kg MBCT	WSLG	SR	Push Up		
		7 Skin folds		1RM BS	L-run			
		Sitting height		VJ				
	Week 3	Tackling	Passing		Catching		Match	Rest
	Week 4	Tackling	Passing		Catching		Match	Rest
	Familiarisation of SCRuM test items to Sub-Elite U19 rugby players							
SE U19	Week 6	Body mass	Yo-Yo	VJ	Speed	RHIE	Match	Rest
		Height	2kg MBCT	WSLG	SR	Push Up		
		7 Skin folds		1RM BS	L-run			
		Sitting height		1RM BP				
	Week 7	Tackling	Passing		Catching		Match	Rest
	Week 8-9	***Familiarisation of SCRuM test items to Elite U16 rugby players***						
E U16	Week 10	Body mass	Yo-Yo	VJ	Speed	Push Up	Match	Rest
		Height	2kg MBCT	WSLG	SR			
		7 Skin folds			L-run			
		Sitting height						
	Week 11	Body mass	Yo-Yo	VJ	Speed	Push Up	Match	Rest
		Height	2kg MBCT	WSLG	SR			
		7 Skin folds			L-run			
		Sitting height						
	Week 12	Tackling	Passing		Catching		Match	Rest
	Week 13	Tackling	Passing		Catching		Match	Rest
	Week 14-15	***Familiarisation of SCRuM test items to sub-elite U16 rugby players***						
SE U16	Week 16	Body mass	Yo-Yo	VJ	Speed	Push Up	Match	Rest

		Height	2kg MBCT	WSLG	SR			
		7 Skin folds			L-run			
		Sitting height						
	Week 17	Tackling	Passing		Catching		Match	Rest
	Week 1-2	***Familiarisation of SCRuM test items to U19 cricket players***						
U19 Cr	Week 3	Body mass	Yo-Yo	WSLG	Speed	Push Up	Match	Rest
		Height	2kg MBCT	VJ	SR	L-run		
		7 Skin folds						
		Sitting height						
	Week 4		Passing		Catching		Match	Rest
	Week 5-6	***Familiarisation of SCRuM test items to U16 cricket players***						
U16 Cr	Week 7	Body mass	Yo-Yo	WSLG	Speed	Push Up	Match	Rest
		Height	2kg MBCT	VJ	SR	L-run		
		7 Skin folds						
		Sitting height						
	Week 8		Passing		Catching		Match	Rest

* represents the time the testing commenced which was exactly 3 weeks after the inception of the SESRL. Yo-Yo=Yo-Yo Intermittent Recovery Level 1 Test; 2kg MBCT=2kg medicine ball chest throw tests; 1RM BP=One repetition maximum bench press test; 1RM BS=One repetition maximum back squat test; WSLG=Wall Sit Leg Strength test; VJ=Vertical Jump test; SR-Sit-and-Reach test; Push Up=60s push up test; RHIE=Repeated High Intensity Exercise Performance Ability test; Match=Represents competitive match; 7 skin folds=biceps, triceps, subscapular, suprailiac, abdomen, thigh, and calf measures. Tackling=Tackling proficiency test; Passing=Passing ability and passing for accuracy for 7m test; Catching=Running and Catching Ability test. E=Elite, SE=sub-elite, Cr=Cricket; U=under

Appendix AI: Compositions of the different versions of the SCRuM test battery per study

Test battery	Study	Anthropometric	Physiological characteristics	Game skills	Other identified
Version A	Narrative literature review	Body mass	Upper body muscular strength	Kicking ability	
		Skin fold measurements	Lower body muscular strength	Ball carrying skills	
		Height	Endurance	Ball possession skills	
		Maturity offset	Anaerobic capacity	Skills under fatigue	
			Speed	Evasion skills	
			Speed endurance	Reactive agility	
			High-intensity intermittent running	Ground skills ability	
			Prolonged high intensity intermittent running ability	Side-step ability	
			High speed running ability	Air and ground skills	
			Prolonged low-intensity running ability	Passing for distance	
			Repeated sprinting ability	Catching ability	
			Repeated effort ability	Passing for accuracy	
			Upper body muscular power	Tackling	
			Lower body muscular power	Rucking	
			Agility/Change of direction speed	Mauling	
			Muscle flexibility	Defensive skills	
			Maximal aerobic capacity	Offensive skills	
			Maximal aerobic power	Scrummaging	
				Lifting	
				Jumping	
				Throwing	
				Game alertness	
Version B	Qualitative study	Body mass	Upper-body muscular strength	Passing	Auditory skills
		Height	Lower-body muscular strength	Kicking	Visual skills
		Body composition	Total muscular power		Anticipatory skills
				Catching	
			Upper-extremity power	Tackling	Decision making

		Lower-extremity Agility Endurance Speed Repeated running Anaerobic capacity Balance Coordination Muscle flexibility Repeated high intensity effort	Evasion Ball handling skills Defensive skills Offensive skills	Game sense Adaptability Communication skills Leadership Competitiveness Mental strength Emotionally stable Positive attitude Courageous Determined Disciplined
Version C	Systematic review	Speed Repeated-sprint ability Repeated-effort ability Repeated high intensity exercise performance Prolonged high-intensity intermittent running ability/Endurance Maximal aerobic power/uptake Maximal aerobic speed/Anaerobic speed reserve Anaerobic capacity Change of direction speed/Agility Lower body muscular power Lower body muscular strength Upper body muscular power Upper body muscular strength Upper body muscular endurance Abdominal endurance	Reactive agility Pattern prediction Pattern recognition Tackling Catching Passing Reactive passing Tackling under fatigue Scrummage Simulated rugby games Game-skills during match Kicking Two-on-one attacking drill Playing ability assessed by coach	

FIRST VERSION OF SCRuM TEST BATTERY	Amalgamated findings from version A, B, C	Body mass	Speed	Reactive agility
		Height	Repeated sprinting ability Repeated effort ability test	Tackling proficiency Catching ability
		Triceps skinfolds	Repeated high-intensity exercise performance ability test	Kicking
		Biceps skinfolds	Prolonged High intensity Intermittent running ability/endurance	Passing-for-distance
		Subscapular skinfolds	Maximal aerobic power	Passing-for-accuracy
		Suprailiac skinfolds	Anaerobic capacity	
		Abdomen skinfolds	Change of direction speed/agility	
		Thigh skinfolds	Lower-body muscular power	
		Calf skinfolds	Lower-body muscular strength Upper body muscular power Upper body muscular strength Upper body muscular endurance Abdominal endurance	
SECOND VERSION OF SCRuM TEST BATTERY	Face validation study	Body mass	Speed	Reactive agility
		Height	Repeated sprinting ability	Tackling proficiency
		Sitting height	Repeated effort ability	Catching ability
		Triceps skinfolds	Repeated high intensity exercise performance ability	Kicking
		Biceps skinfolds	Prolonged high intensity intermittent running ability/Endurance	Passing-for-distance
		Subscapular skinfolds	Anaerobic capacity	Passing-for-accuracy
		Suprailiac skinfolds	Change of direction speed/agility	

		Abdomen skinfolds Thigh skinfolds Calf skinfolds	Lower-body muscular power Lower-body muscular strength Upper-body muscular strength Upper-body muscular power Upper-body muscular endurance Abdominal endurance	
THIRD VERSION OF SCRuM TEST BATTERY	First content validation study	Body mass	Speed	Reactive agility
		Height	Repeated high intensity exercise performance ability	Tackling proficiency
		Sitting height	Prolonged high intensity intermittent running ability/Endurance	Catching ability
		Triceps skinfolds	Anaerobic capacity	
		Biceps skinfolds	Change of direction speed/agility	
		Subscapular skinfolds	Lower-body muscular power	Passing-for-accuracy
		Suprailiac skinfolds	Lower-body muscular strength	
		Abdomen skinfolds	Upper-body muscular strength	
		Thigh skinfolds	Upper-body muscular power	
		Calf skinfolds	Repeated sprinting ability	
FOURTH VERSION OF SCRuM TEST BATTERY	Second content validation study	Body mass	Speed	Reactive agility
		Height	Repeated high intensity exercise performance ability	Tackling proficiency
		Sitting height	Prolonged high intensity intermittent running ability/Endurance	Catching ability
		Triceps skinfolds	Muscle flexibility	
		Biceps skinfolds	Change of direction speed/agility	
		Subscapular skinfolds	Lower-body muscular power	Passing-for-accuracy

		Suprailiac skinfolds	Lower-body muscular strength	
		Abdomen skinfolds	Upper-body muscular strength	
		Thigh skinfolds	Upper-body muscular power	
		Calf skinfolds	Repeated sprinting ability	
FIFTH VERSION OF SCRuM TEST BATTERY	Practical feasibility study	Body mass	Speed	Tackling
		Height	Repeated high-intensity exercise performance ability	Passing for accuracy
		Sitting height	Prolonged High-intensity intermittent running ability/Endurance	Catching
		Triceps skinfolds	Muscle flexibility	Reactive agility test-found not practically feasible
		Biceps skinfolds	Change of direction speed/agility	
		Subscapular skinfolds	Lower-body muscular power	
		Suprailiac skinfolds	Upper-body muscular power	
		Abdomen skinfolds	Upper-and-lower muscle strength tests found not practically feasible	
		Thigh skinfolds		
		Calf skinfolds		
SIXTH VERSION OF SCRuM TEST BATTERY	Test-retest reliability study for U19s	Body mass	Speed	Tackling
		Height		Passing ability
		Sitting height	Agility/Change of direction speed	Catching ability
		Triceps skinfolds	Lower body muscular power	
		Biceps skinfolds	Muscle flexibility	
		Subscapular skinfolds	Upper-body muscular power	
		Suprailiac skinfolds	Upper-body muscular strength	
		Abdomen skinfolds	Lower-body muscular strength	

		Thigh skinfolds	Repeated high intensity exercise performance ability	
		Calf skinfolds	Prolonged high intensity intermittent recovery	
SIXTH VERSION OF SCRuM TEST BATTERY	Test-retest reliability study for U16s	Body mass	Speed	Tackling
		Height		Passing ability
		Sitting height	Agility/Change of direction speed	Catching ability
		Triceps skinfolds	Lower body muscular power	
		Biceps skinfolds	Muscle flexibility	
		Subscapular skinfolds	Upper-body muscular power	
		Suprailiac skinfolds	Upper-body muscular strength	
		Abdomen skinfolds	Lower-body muscular strength	
		Thigh skinfolds	Prolonged high intensity intermittent recovery	
		Calf skinfolds		
SEVENTH VERSION OF SCRuM TEST BATTERY	Construct validity study for U19s		40m sprinting ability (speed)	Passing ability
			Upper-body muscular power	
			Upper-body muscular strength	
			Lower-body muscular strength	
			Repeated high intensity exercise performance ability	
SEVENTH VERSION OF SCRuM TEST BATTERY	Construct validity study for U16s		Lower-body muscular power	Tackling
			Prolonged high-intensity intermittent running ability	Catching ability

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Anthropometric, physiological characteristics and rugby-specific game skills discriminating Zimbabwean under-16 male adolescent rugby players by level of competition

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ABSTRACT

Objectives Despite growing popularity of adolescent rugby in Zimbabwean schools, little is known about qualities or skills of schoolboy rugby players and how they differ by competitive level. Therefore, the aim of the current study was to identify anthropometric, physiological characteristics and rugby-specific game skills capable of discriminating under-16 (U16) RU players across three proficiency levels.

Methods Following development of School Clinical Rugby Measure test battery, elite rugby players (n=41), subelite rugby players (n=30) and non-rugby players (n=29) were enrolled and tested for height, sitting height, body mass, skinfolds, speed, agility, upper and lower muscular strength and power, prolonged high-intensity intermittent running ability, tackling, passing and catching in a cross-sectional study.

Results Elite rugby players displayed significantly better scores for all physiological tests and game skills compared with either subelite or non-rugby players, except for Sit-and-Reach, 20 m speed and L-run tests. However, only vertical jump (VJ) and Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IRT L1) significantly improved with increasing competitive level. In addition, elite rugby players showed significantly better scores for tackling ($p<0.001$) and catching ($p<0.001$) compared with subelites. No statistical differences were observed across competitive levels for height ($p=0.43$), sum of seven skinfolds ($p=0.26$) and passing ($p=0.27$).

Conclusion Since VJ and Yo-Yo IRT L1 improved with increasing playing standard, these findings possibly highlight physiological attributes important in elite schoolboy rugby in Zimbabwe. Additionally, development and training of tackling and catching skills in U16 schoolboy rugby is important since they are linked to higher playing standard.

What are the new findings?

- ► Vertical jump test scores significantly improve with increasing level of competition in under-16 (U16) Zimbabwean schoolboy rugby players.
- ► The Yo-Yo Intermittent Recovery Level 1 test effectively discriminated Zimbabwean elite U16 rugby players from sub-elite or non-rugby players and concomitantly, discriminated subelite from non-rugby players.
- ► Better tackling proficiency and catching ability are linked to attainment of elite status in schoolboy rugby among U16 players in Zimbabwe.

INTRODUCTION

Worldwide, rugby union (RU) is played across a wide age spectrum from junior to senior level.[1] Notwithstanding its popularity in young 'novices' between 9 and 11 years,[2] serious competitive RU commences in adolescence especially at the under-16 (U16) age category.[3 4] Importantly, this period marks the transitional phase between younger (13–15 years) and older (17–18 years) rugby age categories. Moreover, adolescent RU is physically and technically demanding requiring young players to have fitness components and technical skills commensurate with level of competition.[5] As such, an assessment of qualities or skills for U16 male adolescents involved in competitive rugby and how these attributes differ by level of competition is important.

Although there are numerous studies documenting the characteristics of male adolescents playing U13 to U19 competitive rugby,[6–13] no such studies have been conducted for Zimbabwean school-based adolescent male rugby players. Therefore, there is limited understanding of the qualities of Zimbabwean U16 rugby players playing competitive rugby and how they differ by playing standards. This is a significant shortcoming given the increased popularity RU is currently enjoying in Zimbabwean schools.[14] Population differences between studies limit extrapolation of data from other countries to inform contextual strategies on talent identification and team selection. However, the general notion in literature is that male adolescent rugby players should be bigger, faster, fitter and more powerful to reflect the collision nature of the sport.[9] Against that background, this study was conducted to identify anthropometric variables, physiological characteristics and rugby-specific game skills discriminating elite U16 rugby players from subelite and non-rugby players, and concomitantly, differentiating subelite rugby players from non-rugby players. It was hypothesised that anthropometric, physiological characteristics and rugby-specific game skills would improve with increasing playing standard (elite vs subelite vs non-rugby players). These findings may facilitate rugby coaches' understanding of the general attributes contextually important for U16 school athletes to participate in rugby (subelite rugby players vs non-rugby players) and the specific attributes in need of training for the attainment of elite rugby status at U16 age category (elite rugby players vs subelite rugby players).

METHODS

Research design and participants

This study utilised a cross-sectional experimental design and had 41 elite, 30 subelite and 29 non-rugby players. The term 'elite' and 'subelite' referred to adolescents playing competitive rugby in the Super Eight Schools Rugby (SESRL) and Co-educational Schools Rugby League (CESRL), respectively. The SESRL is the premier high school rugby league in the country and CESRL is the second most competitive league.[15] The non-rugby players represented U16 high school cricket players. The rationale for selecting cricket players was based on having an organised and convenient group of athletes with some degree of physical fitness derived from a sport diametrically opposed to rugby in terms of physical and technical demands. Written informed assents and consents were provided by the participants and parents/guardians, respectively.

Procedures

All selected players undertook protocol assessments based on the School Clinical Rugby Measure (SCRuM) test battery (online supplementary file 1). Briefly, the test battery included anthropometry (height, sitting height, body mass, seven skinfold site measurements), physiological characteristics (speed, agility, upper and lower muscular strength and power, muscle flexibility, prolonged high-intensity intermittent running ability/endurance) and rugby-specific game skills (tackling proficiency test, passing ability skills test and running and catching ability skills test). The development of the SCRuM test battery and the rationale for inclusion of the selected tests for the corresponding variables has been described elsewhere.[15]

Before the actual testing, all eligible participants were first familiarised to the test items in SCRuM test battery on two consecutive days. Elite U16 male rugby players were then tested twice to estimate the absolute and relative reliability of each SCRuM test item. Singe measure intraclass correlation coefficients (ICC) for two-way random effects (ICC 2, 1) reporting for absolute agreement and coefficient of variation (%) values are presented for each test item (online supplementary file 1). Baseline results for these players were then compared with data obtained from U16 subelite rugby players and non-rugby players. All rugby players were tested during training and during the rugby competitive season (June–August 2018) by trained research assistants. Experimental test sessions for the cricketers were conducted during the cricket competitive season (September–October 2018). At any day of testing, injured or ill participants were excluded. Each test would be fully explained, demonstrated and then participants would perform standardised warm-up procedures and three submaximal practice trials.

Statistical analysis

SPSS statistical software V.25.0 was used for analysis, with statistical significance accepted when $p<0.05$. Shapiro-Wilk's test assessed normality for all continuous variables. Parametric data are presented as mean±SD. Using general linear model, univariate one-way analysis of variance (ANOVA) compared group means for each dependent variable by level of competition. In case of significant effects, the Scheffe's post hoc test determined the location of the mean differences given equal variances. Otherwise, for unequal variances, comparisons were performed using the Games Howell test. Independent sample t-test analysed for differences between elite and subelite rugby players for the rugby-specific game skills. Cohen's d effect sizes (ES) were calculated and interpreted as follows: <0.2 (trivial), 0.2–0.6 (small), >0.6–1.2 (moderate) and >1.2 (large).[16]

RESULTS

The table 1 shows group comparisons for demographic and SCRuM test items. Online supplementary file 2 compares raw scores for the elite U16 rugby players in the present study with similar age groups in other previous studies from other countries, showing relatively lower values for the Zimbabwean cohort. Overall, no statistically significant differences were observed for sum of seven skinfolds ($F=1.38$, $p=0.26$), chronological age ($F=1.18$, $p=0.31$), playing experience ($F=1.68$, $p=0.19$) across competitive levels and passing ability skill test ($t=1.12$, $p=0.27$) between groups. Elite U16 rugby players performed significantly better ($p<0.05$) for all physiological characteristics and rugby-specific game skills than the other groups, except for the Sit-and-Reach test. The non-rugby players had significantly better muscle flexibility compared with the rugby players regardless of competitive level ($F=9.35$, $p<0.001$). Only vertical jump (VJ) and Yo-Yo Intermittent Recovery Level 1 (Yo-Yo IRT L1) effectively discriminated elite U16 rugby players from both subelite rugby players and non-playing rugby players and further differentiated subelite rugby players from non-rugby players. The 20 m speed test ($F=2.59$, $p=0.08$) and L-run agility test ($F=2.28$, $p=0.11$) showed

Table 1 Group comparisons for demographic, anthropometric, physiological characteristics and game-specific skills for U16 elite, subelite and non-rugby players

	Elite* (n=41)	Subelite† (n=30)	Non-rugby‡ (n=29)	One way ANOVA			Effect size* †	Effect size*‡	Effect size†‡
	Mean±SD	Mean±SD	Mean±SD	F	P	Post hoc analysis			
Chronological age (years)	14.9±0.31	14.8±0.43	14.9±0.28	1.18	0.31		0.27	0.00	0.28
Playing experience (years)	2.49±0.51	2.23±0.68	2.38±0.56	1.68	0.19		0.43	0.21	0.24
Anthropometrics									
Body mass (kg)	63.7±9.09	61.2±15.5	56.1±7.83	3.95	0.02	1>3	0.20	0.90§	0.42
Height (m)	1.67±0.08	1.68±0.08	1.66±0.08	0.89	0.43		0.13	0.13	0.25
Biceps (mm)	5.78±1.70	6.64±1.14	7.00±3.91	2.30	0.11		0.59	0.40	0.13
Triceps (mm)	9.85±3.25	9.86±1.94	10.8±5.89	0.55	0.58		0.00	0.20	0.21
Subscapular (mm)	10.9±2.86	11.3±2.70	12.5±6.21	1.30	0.28		0.14	0.33	0.25
Suprailiac (mm)	8.28±2.97	8.90±2.99	9.97±5.46	1.64	0.20		0.21	0.38	0.24
Abdomen (mm)	11.4±4.51	12.6±2.86	12.4±6.34	0.65	0.53		0.32	0.18	0.04
Thigh (mm)	10.7±3.84	11.4±2.29	11.7±4.40	0.69	0.50		0.22	0.24	0.09
Calf (mm)	6.49±1.55	7.72±1.17	7.73±3.48	3.71	0.03	1<2, 3	0.90§	0.46	0.00
Sum of seven skinfolds (mm)	63.4±17.1	68.4±10.5	72.1±33.1	1.38	0.26		0.35	0.33	0.15
Physiological tests									
10m speed (s)¶	2.19±0.14	2.24±0.16	2.33±0.19	6.09	<0.001	1<3	0.33	0.84§	0.51
20m speed (s)¶	3.50±0.22	3.55±0.22	3.63±0.24	2.59	0.08		0.23	0.56	0.35
40m speed (s)¶	6.14±0.46	6.20±0.60	6.47±0.47	4.39	0.02	1<3	0.11	0.71§	0.50
L-run test (s)¶	6.49±0.34	6.62±0.46	6.67±0.27	2.28	0.11		0.32	0.59	0.13
Vertical jump test (cm)[wg]	38.3±2.38	34.9±2.82	32.6±4.12	29.9	<0.001	1>2, 3; 2>3	1.30§	1.69§	0.65§
Sit-and-Reach (cm)[wg]	6.12±5.10	5.05±4.57	8.56±2.01	9.35	<0.001	1, 2<3	0.22	0.63§	0.99§
2kg Medicine ball chest throw (m)[wg]	6.97±0.64	5.91±0.86	5.83±0.86	26.2	<0.001	1>2, 3	1.40§	1.50§	0.09
60s Push Up (n)	38.4±10.1	35.6±8.90	32.6±7.06	3.61	0.03	1>3	0.29	0.67§	0.37
Wall Sit Leg Strength (s)[wg]	132.1±6.61	123.3±13.0	121.2±23.0	10.2	<0.001	1, 2>3	0.85§	0.64§	0.11
Yo-Yo Intermittent Recovery Level 1 (m)[wg]	1307.3±228.6	1030.7±269.6	897.9±171.7	36.6	<0.001	1>2, 3; 2>3	1.11§	2.03§	0.59
Game skills									
Tackling proficiency test (%)	83.0±8.87	68.3±7.94	–	7.12**	<0.001		1.75§		
Passing ability test (au)	105.9±4.86	104.7±4.34	–	1.12**	0.27		0.26		
Catching ability test (au)	71.7±2.06	68.3±2.56	–	6.19**	<0.001		1.46§		

Playing experience=playing and training experience of competitive sport either rugby or cricket; catching ability=running and catching ability test; F= F test for analysis of variance reporting the p value.
*Elite.
†Subelite.
‡Non-rugby.
§Moderate to large Cohen's d effect size (moderate effect: 0.6–1.2; large effect >1.2).
¶Sample size was 26 for the subelite rugby players who performed these tests.
**The t-test results for between two groups comparisons.
wg, Welch F test reported and Games Howell test used for the post hoc analysis.

no significant differences across playing standards. In terms of the rugby-specific game skills, elite rugby players showed better tackling proficiency (t=7.12, p<0.001, ES=1.75) and running and catching abilities (t=6.19, p<0.001, ES=1.46) than their subelite counterparts, with large practical differences between groups.

DISCUSSION

The main finding of this study was that VJ and Yo-Yo IRT L1 significantly improved with increasing competitive level. Another key finding was that elite U16 RU players showed significantly superior scores for rugby-specific game skills of tackling and catching than the sub-elite rugby players. This breadth of discriminant factors highlights the importance of physiological characteristics and rugby-specific game skills in competitive RU for elite U16 schoolboys. Specifically, these findings indicate that well-developed lower-body muscular power, prolonged high-intensity intermittent running ability/endurance, tackling proficiency and catching ability skills are possibly linked to the attainment of elite status in Zimbabwean U16 rugby players playing competitive schoolboy RU.

From the current study, it is unclear whether these findings indicate efficient specialist training of lower-body muscular power, endurance, tackling and catching among U16 elite rugby players or preferential recruitment of powerful, physically enduring U16 players with better tackling and catching abilities in SESRL. It is also possible that both factors could account for the differences between groups. Given similar playing experience between groups, this probably negates the possible influence of playing history on test performances. However, specific details on the content or structure of the training routines for the elite, subelite and non-rugby players were not captured. Probably, this information is helpful in explaining the discriminant ability of VJ, Yo-Yo IRT L1, tackling and catching tests. Nevertheless, the current findings practically inform schoolboy coaches on the specific attributes required by schoolboy rugby players for the attainment of elite status in U16 competitive rugby through training in Zimbabwe.

There are limited studies specifically comparing anthropometric, physiological characteristics and rugby-specific game skills of U16 male adolescent RU players in the literature. Most studies offer a comparative analysis of adolescent rugby players from different age categories.[3 7 8 12] Although such studies provide data which has implications on identifying key characteristics in rugby, the main limitation of such studies is that between-group differences may reflect the possible influence of age, growth and biological maturation. Spamer *et al*[11] compared characteristics of U16 rugby players from New Zealand (NZ, higher level) and South African (SA, lower level). Such age-specific comparisons are more likely to provide highly relevant information on the attributes important for rugby at the specified age category with little or no possible influence of age or maturity. Training differences, habituation or coaches' selection biases become fundamentally important in accounting for the observed test performances among same-aged players with different playing abilities.[6] In the latter study, the elite NZ U16 players showed higher scores for VJ (ES=0.9) than elite SA U16, possibly reflecting superior explosive power capabilities in higher-level athletes.

Given no differences in sum of skinfolds observed across playing standards, the fact that elite U16 RU players had greater body mass than cricketers (ES=0.90) suggest increased lean mass for the elite RU players. Reportedly, increased muscle mass is an important determinant of muscle strength.[17] This probably explains better upper and lower muscular strength values for the elite U16 compared with other groups. Moderate practical significant differences (ES=0.67) were observed for the 60s Push Up test and Wall Sit Leg Strength test (ES=0.64) between elite and cricket players. Since greater levels of muscular strength are likely to produce better power output,[17] this probably explains the high upper-and-lower body muscular power performances of elite U16 rugby players compared with other groups. The implications of these results are that schoolboy rugby coaches may aim to devise training methods facilitating development of muscular strength and power to enhance playing potential of non-rugby or subelite players during talent identification and recruitment.

Jones *et al*[6] compared the physical qualities of academy (higher level) and school-level (lower level) U18 RU players observing small practical differences between groups for the Yo-Yo IRT L1. However, in the current study, elite U16 rugby players had better Yo-Yo IRT L1 test scores than subelite rugby players (ES=1.11) and non-rugby players (ES=2.03). Population and age-related differences could explain results discrepancy between Jones *et al*[6] and the current study (U18 RU English vs U16 RU Zimbabwe). Given these differences, it is also possible that endurance qualities may have a greater impact in determining higher playing standards in U16 RU than in U18 RU.

In a related sport of rugby league (RL), Johnston *et al*[18] found that the high-standard junior players (16.6±0.5 years) covered greater distances compared with the low-standard players (16.5±0.6 years) on the Yo-Yo IRT L1 (1420±337m vs 922±227m). Although these findings relate to a different sport, they add support to the possibility of endurance qualities having greater discriminative ability in younger adolescents playing competitive intermittent team sports. The latter authors attributed the differences to increased physical demands associated with higher standards of competition necessitating optimal physical fitness levels in participating players. In the current study, the fact that subelite rugby players also showed high scores for the Yo-Yo IRT L1 relative to the non-rugby players is an indication that endurance is an important fitness component in the sport of rugby than in cricket. From a practical perspective, schoolboy coaches should continuously emphasise the development of endurance in potential adolescent rugby players identified or selected for U16 rugby competitions.

In the present study, 10 m, 20 m and 40 m speed tests failed to discriminate elite U16 rugby players from their subelite counterparts. Although in RL, Till *et al*[19] also showed no significant differences in the 10 m and 20 m sprints among U15 players playing amateur (15.6±0.25 years), academy (15.6±0.29 years) and professional rugby (15.5±0.30 years). Jones *et al*[6] reported consistent results for 10 m, 20 m and 40 m speed tests between academy and school-level U18 RU players. Lack of speed differences between rugby players probably dismisses sprinting abilities as important determinants of higher playing standards in Zimbabwe schoolboy rugby or shows its equal importance in both competitive leagues and the need for continued training. Evidence from a recent systematic review showed that speed is the most commonly investigated physiological characteristic among rugby players especially 10 m, 20 m and 40 m sprint time.[20] Similarities in chronological age, playing experience, body mass, height and skinfolds between the elite and the subelite players probably explain the similar sprinting time.

Another important finding of this study was that elite U16 rugby players had better scores for tackling and catching compared with subelite rugby players. Cognisant of the cross-sectional design of the study, these findings suggest that tackling proficiency and catching ability skills could be used in the Zimbabwean context to discriminate U16 RU playing at different levels of competition. Practically, this hints to the coaches the importance of skill training incorporating tackling and catching skills among U16 RU players. A recent review showed that tackling and catching represent important technical elements in rugby and are commonly evaluated among rugby players.[21] However, there are limited studies comparing game-specific skills of elite U16 to subelite U16 RU players in the literature. Studies from related intermittent contact team sports such as RL which also emphasise tackling and catching have reported consistent results. For example, Gabbett *et al*[22] showed that first-grade RL players (23.7±4.3 years) had greater catching ability scores compared with second-grade players (24.4±5.0 years). In another study, Gabbett *et al*[23] showed differences in tackling proficiency between the lesser-skilled (22.3±3.5 years) and the higher-skilled RL players (24.6±3.9). The present study findings lend support to the possible discriminative ability of tackling and catching although at U16 competitive level in schoolboy RU. Given the similar ages and playing experiences between elite and subelite players, other factors such as differences in upper and lower body muscular power and specific training approaches for technical skills may also account for the discriminative ability of these tests in the current study. The significantly higher VJ and 2 kg Medicine Ball Chest Throw (2 kg MBCT) scores for elite U16 RU players would certainly advantage the arm-wrapping capabilities of the tackler and leg drive performances during tackle execution.[24]

An unexpected finding for the present study was the small effect size differences between the elite and subelite U16 for the passing ability skill test. This was despite the elite players showing better tackling and catching skills. Given the importance of passing in rugby as evidenced by the number of studies investigating the passing ability of RU or RL players,[21] these findings probably indicate similar proficiency in passing abilities between elite and subelite U16 RU playing competitive rugby in Zimbabwean schools. Consistently, passing components failed to show discriminative ability between NZ U16 players and SA U16 rugby players.[11] This was largely because the two groups were a representation of elite players in their respective countries. Also, Gabbett *et al*[22] shared similar findings of no statistically significant difference in basic passing skills between first-grade (23.7±4.3 years) and second-grade (24.4±5.0 years) RL players. However, there were significant differences between first (23.7±4.3 years) and third grade (17.8±1.5 years) players possibly reflecting the influence of different ages, playing and training experience (online supplementary file 1)[25–46].

This study had some limitations that need consideration when interpreting obtained results. Due to lack of technical competency and local cricket coaches' reservations, U16 cricket players were not assessed for game-specific skills. This indirectly points out to the importance of these technical abilities to the sport of rugby. A further limitation of the present study was cross-sectional examination of players representing one age-category conveniently derived from selected schools. This limits generalisability of the study findings to other age groups and to rest of the schoolboy rugby players playing U16 RU in Zimbabwe. Future studies in this area of research may aim to compare playing at different age categories (U16 vs U19) or include a large random sample of U16 from various school teams playing in the SESRL and CESRL. The sample size was small to allow for player position categorisation. Participant testing was conducted during the rugby and cricket competitive season during training hours. The possible influence of residual fatigue may have influenced the cross-sectional test performances. However, an attempt was made to intersperse with 48 hours the performance of the most physically demanding tests. The SCRuM test battery only had anthropometric, physiological and coach-rated rugby skills in its multidimensional attempt; however, a more holistic test battery encompassing all the elements important in rugby such as technical, tactical and psychological measures would have been appropriate. The selection of cricket players as a control group was arbitrary decision premised on reported differences in physical, physiological and technical demands with rugby. However, it is possible that there could be certain competencies that could be similar between the sports influencing the observed results.

CONCLUSION

The present study set to identify anthropometric, physiological and rugby-specific skills discriminating U16 RU players by level of competition. Although elite U16 RU players demonstrated superior scores for most physiological characteristics and game-specific skills compared with subelite and non-rugby players, only the test scores for VJ, Yo-Yo IRT L1, tackling and catching ability skills tests significantly improved with increasing competitive level. Such findings implies that lower-body muscular power, prolonged high intensity intermittent running ability, tackling and catching effectively discriminates elite rugby players from subelite and non-rugby players and also differentiates subelites from the non-rugby players. From a practical perspective, schoolboy rugby coaches need to facilitate the development and maintenance through continuous training of such qualities and skills among U16 schoolboy rugby players.

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Contributors MC, BCMS-E and GDF originally developed the concept and design of the study. MC is a doctoral student at UCT and this manuscript is part of his doctoral thesis. MC acted as the lead investigator under the guidance, mentorship and supervision of BCMS-E and GDF. MC conducted the literature review, recruited and trained research assistants and participants with variable assistance coming from other people who were acknowledged in the acknowledgment section. MC supervised the data collection. MC drafted the manuscript for publication and acted as the corresponding author. BCMS-E and GDF performed critical revision of the manuscript, statistical input, and provided extensive revisions prior to submission to the journal for review. All the authors read and approved the final version of the manuscript.

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Appendix AK: Research publication with U19 data

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BMC Research Notes

RESEARCH NOTE — Open Access

Qualities or skills discriminating under 19 rugby players by playing standards: a comparative analysis of elite, sub-elite and non-rugby players using the SCRuM test battery

M. Chiwaridzo*, G. D. Ferguson and B. C. M. Smits-Engelsman

Abstract

Objective: Although schoolboy rugby is growing in popularity and played at different competitive levels in Zimbabwe, the influence of playing standard on qualities or skills of older male adolescent rugby players is unknown. Utilising a cross-sectional design, this study determined anthropometric, physiological characteristics and rugby-specific game skills defining elite under 19 (U19) schoolboy rugby players. Following development and subsequent assessment of test–retest reliability of School Clinical Rugby Measure (SCRuM) test battery, this study compared performance outcomes of elite rugby players ($n = 41$), sub-elite rugby players ($n = 46$) and non-rugby athletes ($n = 26$) to identify qualities or skills discriminating (i) elite from sub-elite and non-rugby players, and concomitantly (ii) sub-elite from non-rugby players.

Results: 40 m speed test ($p < 0.001$, $ES = 1.78$) and 2 kg Medicine Ball Chest Throw test ($p < 0.001$, $ES = 1.69$) significantly discriminated elite U19 from sub-elite and non-rugby players. These tests further differentiated sub-elite from non-rugby athletes. Additionally, 1RM back squat ($p = 0.009$, $ES = 0.57$), 1RM bench press ($p = 0.005$, $ES = 0.61$), repeated high-intensity exercise test ($p < 0.001$, $ES = 0.88$) and passing ability test ($p < 0.001$, $ES = 0.99$) discriminated elite from sub-elite counterparts. These findings highlight important attributes linked to elite U19 schoolboy rugby in Zimbabwe. However, no significant differences were observed for sum of seven skinfold ($p = 0.28$), tackling ($p = 0.08$) and catching ability ($p = 0.05$).

Keywords: Rugby, Under 19, SCRuM, Physiological, Anthropometric, Rugby skills

Introduction

Lately, research examining characteristics of schoolboy rugby union (RU) players has increased [1–4]. This has been necessitated by expanding participation rates in a combative sport known for high injury risk and match/training volumes [2, 5–10]. Moreover, the reported high physical and technical demands of adolescent RU [1, 5] require junior players to have optimal qualities or technical proficiencies for effective participation. Therefore, research defining key attributes important in competitive schoolboy RU is warranted especially in Zimbabwe where schoolboy RU is emerging and played at different competitive levels [11, 12]. Such evidence has implications on talent identification (TID) and long-term player development [13].

To understand player attributes important in RU, previous studies compared schoolboy RU players by playing standards at U13 [14], U16 [15] and U18 level [13, 16]. For most of these studies [14–16], the influence of playing standard was examined by comparing performance

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outcomes of elite adolescent RU players playing in two countries of different playing abilities. Observed differences between studies reflect differences in lifestyle, socio-economic, environmental, training philosophies, and TID initiatives among other factors. In contrast, Jones et al. [14] compared physical qualities of U18 RU players playing at different standards (academy rugby vs. school rugby) in England. The identified qualities differentiating academy from school-level RU players possibly suggest important variables contributing to a higher playing standard in U18 RU.

Given the important influence of increasing age in player characteristic development [17], U19s are an important group to target since they represent a group transitioning into senior professional rugby. To understand the attributes defining good U19 schoolboy rugby players, this study compared anthropometric and physiological characteristics across differing playing standards of elite, sub-elite and non-rugby players, and further compared rugby-specific game skills between elite and sub-elite RU players. It was hypothesised that test performances would improve significantly with increasing playing standards.

Main text

Study design, setting and participants

This study formed part of the School Clinical Rugby Measure (SCRuM) project described elsewhere [11, 12, 18] and was conducted in two sequential parts. Adopting a pragmatic "in-season" approach previously used by Enright et al. [19], the preliminary study established the absolute and relative reliability of each test item in the assembled SCRuM test battery. Forty-one elite U19 schoolboy rugby players completed all tests (Fig. 1) with 7 days separating test–retest assessments. The participants were recruited from one school based in Harare, Zimbabwe playing rugby in the Super Eight Schools Rugby League (SESRL). The SESRL is the most competitive schoolboy rugby league in Zimbabwe [20]. Participant testing commenced in third week from the inception of SESRL season in May 2018 (Additional file 1). Participants with self-reported injuries or any other health-related condition precluding participation in physical activity were excluded.

Utilising a cross-sectional design, the main study compared test performances of three groups of athletes. The study used baseline reliability data for elite players. Sub-elite participants were U19 male adolescent players ($n=46$) recruited from a school playing in the Co-educational Schools Rugby League (CESRL). The CESRL represents a second-tier schoolboy rugby league [18]. Also, U19 schoolboy cricket players ($n=21$) from one top cricket-playing school represented non-rugby athletes. The cricket players were included as a second comparative group composed of elite athletes playing a sport known to have differing physical and technical demands than rugby [21, 22]. This study was approved by University of Cape Town Human Research Ethics Committee (HREC: 016/2016). Written informed assent and consent were obtained from participants and parents respectively.

Procedures

All eligible athletes undertook assessments in the SCRuM test battery (Additional file 2). The rationale and processes of assembling the test battery and its subsequent evaluation of face, logical validity and practical feasibility have been described elsewhere [18]. Subsequently, test–retest reliability of each SCRuM test item was established in the preliminary study using elite U19 rugby participants. Before testing, all participants were familiarised to the test battery on 2 consecutive days. Baseline results for these players were compared to data obtained from U19 sub-elite and non-rugby players. Sub-elite rugby players were tested during mid-season of the CESRL (June 2018). However, all the testing for cricket players happened during cricket competitive season (September–November 2018). The order of testing was as indicated in Additional file 1.

Data analysis

Statistical analyses were carried out using SPSS version 25.0. Shapiro–Wilk test assessed violations of normality ($p<0.05$). Descriptive statistics (Mean ± SD) described parametric data. Relative reliability was determined using two-way random intra-class correlation coefficient (ICC) for absolute agreement on single measures (Additional file 3). ICCs above 0.7 were considered acceptable [23]. Tests with low ICCs and greater coefficient of variation ($CV>10\%$) [24, 25] were removed. One-way analysis of variance compared group means for each playing standard. However, when equality of variance assumption was violated as assessed by Levene's test, Welch F test results were reported. In case of significant effects ($p<0.05$), Scheffe's posthoc test located the mean differences with equal variances assumed. Otherwise, the Games Howell test was used. Independent t test compared for statistical significance between two groups. The magnitude of the differences in group means were described with Cohen's d effect size (ES) calculated as the difference between group means divided by the pooled standard deviation [26]. The interpretation of ES was as follows: <0.2 trivial, 0.2–0.6 small, >0.6–1.2 moderate and >1.2 large [27, 28].

Results

Table 1 below shows group comparison for SCRuM test items.

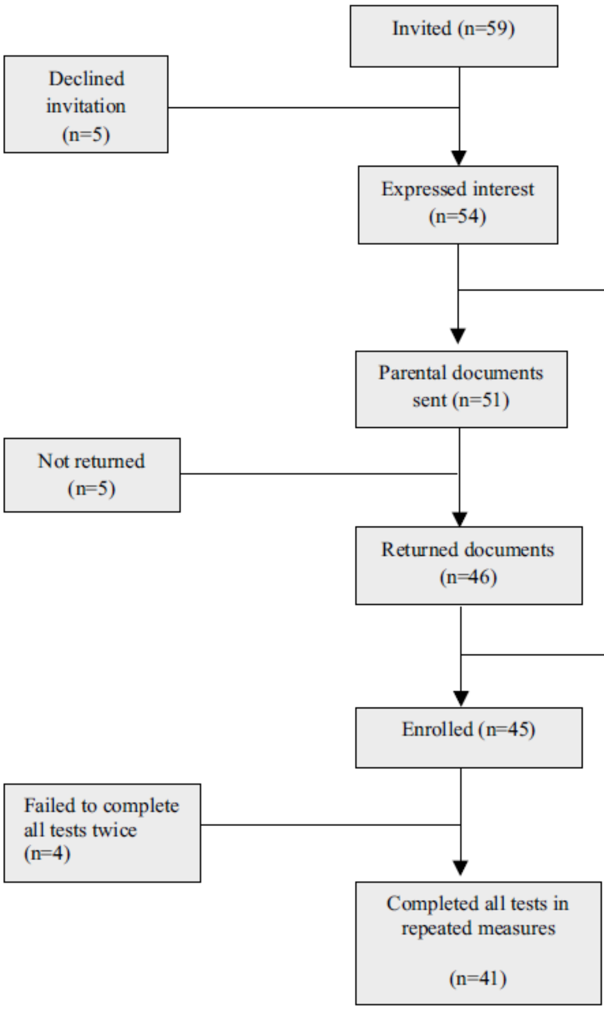

Fig. 1 Flow chart for participants enrolled in the preliminary test–retest reliability study. Parental documents entailed Adolescent Medical Health Questionnaires and Parental Information letters

Discussion

The 40 m speed and 2 kg MBCT tests effectively discriminated elite from both sub-elite and non-rugby players, and concomitantly differentiated sub-elite from non-rugby counterparts. Additionally, 1RM BS, 1RM BP, RHIE, and passing ability skill test differentiated elite from sub-elite rugby players. Collectively, these results suggest the importance of 40 m sprinting ability, upper-body muscular power, upper-and-lower body muscular strength, repeated high-intensity performance ability and passing ability in elite U19 adolescent rugby. Practically, these findings highlight to schoolboy rugby coaches the physiological characteristics and game skills important for training for attainment of “elite” status by sub-elite or non-rugby athletes.

This study showed that elite U19s had higher absolute and relative strength compared to sub-elite players. This was despite both groups reporting equal weekly exposure to supervised resistance training. However, it is unclear whether the content or structure of the resistance training was similar or different for both groups. Moreover, there were no significant differences in playing experience and maturity between groups dismissing possible influence of biological growth and different playing experience in accounting for strength differences. Jones et al. [13] compared physical qualities of 55 U18 professional

Table 1 Group comparisons for demographic characteristics and SCRuM test items by playing standards

	Elite [1] (n = 41)	Sub-elite [2] (n = 46)	Non-rugby [3] (n = 21)	One-way ANOVA			[1] vs [2]. ES	[1] vs [3] ES	[2] vs. [3] ES
	Mean ± SD	Mean ± SD	Mean ± SD	F	P	Posthoc	d	d	d
Age (yrs)	17.5 ± 0.85	17.4 ± 0.87	17.6 ± 0.81	0.14	0.87		0.12	0.12	0.24
Playing exp. (yrs)	4.95 ± 0.74	4.89 ± 0.67	4.74 ± 0.38	1.56	0.24		0.09	0.36	0.28
APHV (yrs)	15.6 ± 0.60	15.8 ± 0.13	15.8 ± 0.58	1.21	0.30		0.46	0.34	0.00
Maturity offset (yrs)	1.93 ± 0.53	1.64 ± 0.97	1.78 ± 0.56	1.61	0.21		0.37	0.28	0.18
Anthropometric tests									
Body mass (kg)	77.5 ± 9.58	75.9 ± 11.6	68.5 ± 9.47	5.40	0.006*	1, 2 > 3	0.15	0.94[a]	0.70[a]
Height (m)	1.73 ± 0.06	1.72 ± 0.08	1.71 ± 0.06	0.30	0.74		0.14	0.33	0.14
Biceps (mm)	6.71 ± 3.62	6.60 ± 3.14	6.57 ± 2.27	0.02	0.98		0.03	0.05	0.01
Triceps (mm)	9.44 ± 2.95	9.83 ± 4.58	8.36 ± 2.69	1.15	0.32		0.10	0.38	0.39
Subscapul. (mm)[wg]	12.8 ± 2.74	13.5 ± 4.64	11.2 ± 2.64	3.73	0.03*	2 > 3	0.18	0.59	0.61[a]
Suprailiac (mm)	8.93 ± 3.84	9.51 ± 3.93	9.52 ± 1.98	0.34	0.71		0.15	0.19	0.00
Abdomen (mm)[w]	11.4 ± 2.85	13.3 ± 5.90	11.8 ± 2.41	1.79	0.18		0.45	0.15	0.33
Thigh (mm)	9.98 ± 2.48	11.0 ± 4.83	9.08 ± 2.00	2.86	0.07		0.27	0.40	0.52
Calf (mm)[w]	5.49 ± 1.03	6.11 ± 2.07	6.17 ± 1.29	3.08	0.05		0.38	0.58	0.03
Sum of SKF (mm)[w]	64.7 ± 15.6	69.8 ± 24.4	62.7 ± 11.6	1.30	0.28		0.25	0.15	0.37
Physiological tests									
20 m speed (s)	3.25 ± 0.17	3.36 ± 0.23[b]	3.47 ± 0.25	8.30	< 0.001*	1 < 2, 3	0.54	1.03[a]	0.46
40 m speed (s)	5.60 ± 0.29	5.84 ± 0.40[b]	6.10 ± 0.27	16.2	< 0.001*	1 < 2, 3; 2 < 3	0.69[a]	1.78[a]	0.76[a]
L-run test (s)	6.21 ± 0.32	6.33 ± 0.33[b]	6.43 ± 0.25	3.65	0.03*	1 < 3	0.37	0.77[a]	0.34
VJtest (cm)	47.8 ± 3.81	42.5 ± 3.84[b]	44.4 ± 3.85	20.5	< 0.001*	1 > 2, 3	1.39[a]	0.89[a]	0.49
2 kg MBCT test (m)	9.23 ± 1.26	8.31 ± 1.18	7.18 ± 1.16	20.4	< 0.001*	1 > 2, 3; 2 > 3	0.75[a]	1.69[a]	0.97[a]
60 s Push Up (n)	49.7 ± 9.97	43.9 ± 12.0	38.2 ± 6.50	8.95	< 0.001*	1 > 2, 3	0.53	1.37[a]	0.59
WSLS test (s)[wg]	146.0 ± 9.72	137.5 ± 21.7	132.6 ± 7.41	18.3	< 0.001*	1 > 2, 3	0.51	1.55[a]	0.30
1RM BS test (kg)	98.4 ± 14.8	89.5 ± 16.3	–	2.68[c]	0.009*		0.57	–	–
Relative BS (kg/kg^{-1})	1.27 ± 0.04	1.17 ± 0.06	–	8.77[c]	< 0.001*		1.96[a]	–	–
1RM BP test (kg)	90.5 ± 16.4	80.6 ± 15.9	–	2.86[c]	0.005*		0.61[a]	–	–
Relative BP (kg/kg^{-1})	1.16 ± 0.08	1.06 ± 0.06	–	6.98[c]	< 0.001*		1.41[a]	–	–
RHIE 1st sprint test (s)	10.2 ± 0.77	10.5 ± 0.81[b]	–	1.87[c]	0.07		0.38	–	–
RHIE 2nd sprint test (s)	13.0 ± 1.02	13.2 ± 0.96[b]	–	0.76[c]	0.45		0.20	–	–
RHIE 3rd sprint test (s)	16.1 ± 1.49	18.2 ± 1.64[b]	–	6.32[c]	< 0.001*		1.34[a]	–	–
RHIE total sprint test (s)	39.3 ± 2.96	41.9 ± 2.97[b]	–	4.04[c]	< 0.001*		0.88[a]	–	–
Decrement in RHIE (s)	5.92 ± 1.17	7.76 ± 1.31[b]	–	6.81[c]	< 0.001*		1.48[a]	–	–
Yo–Yo IRT (m)[wg]	1505.9 ± 75.8	1443.6 ± 259.1[b]	1053.3 ± 148.8	84.5	< 0.001*	1, 2 > 3	0.33	3.83[a]	1.85[a]
Rugby-specific tests									
Tackling test (%)	87.9 ± 8.44	84.8 ± 8.16	–	1.77[c]	0.08		0.37	–	–
Passing ability test (au)[wg]	116.2 ± 2.13	113.0 ± 4.07	–	4.60[c]	< 0.001*		0.99[a]	–	–
Catching ability test (au)[wg]	74.0 ± 1.07	73.5 ± 1.35	–	1.98[c]	0.05		0.41	–	–

[1], Elite group; [2], Sub-elite group; [3], Non-rugby group; Playing exp., Number of years playing competitive schoolboy sport either rugby or cricket; Subscapul. (mm), Subscapular (mm); SKF, Skinfolds; catching ability, running and catching ability test expressed in arbitrary units; SD, standard deviation; F, F test for ANOVA reporting the p value; wg, Welch F test reported and Games Howell test used for the post hoc analysis; w, Welch test results reported because of a significant Levene's test result based on the mean; 2 kg MBCT, 2 kg medicine ball chest throw test; WSLS, Wall sit leg strength test; Yo–Yo IRT, Yo–Yo intermittent recovery test; Tackling proficiency (%), Tackling test expressed as a percentage; 1RM, one repetition maximum; 1RM BS and BP, one repetition maximum bench squat and press respectively; RHIE, repeated high intensity exercise test measured in seconds; no cricket players were allowed to perform 1RM BP, 1RM BS and RHIE because of lack of training exposure to these physically demanding tests; au, arbitrary units

[a] Denotes moderate to large effect sizes for within age-group comparison using the Cohen d; *d*, effect size APHV, predicted age at peak height velocity based on prediction equations reflecting the estimated age at maximal velocity of growth in height during the adolescent spurt; Maturity offset (years), predicted years before or after age peak height velocity (APHV). The chronological age (CA) at prediction minus offset provides an estimate of APHV; VJ test, vertical jump test

[b] , sample size was 44 for the specified running tests

[c], t-test independent samples test results comparing two groups; Posthoc, refers to the Scheffe or games Howell test results; Decrement in RHIE, Decrement in RHIE sprint performance calculated as the difference in time taken (seconds) to complete the third set of sprints (sprints 7–9) compared with the total time taken to

Table 1 (continued)

complete the first set of 3 sprints (sprints 1 − 3) denoting fatigue time; d sample size was 26 for the respective tests; ES, effect size; One-way ANOVA, one way analysis of variance

* Significant p values for the ANOVA F test; 5 m speed, 10 m speed, sit and reach tests and passing for accuracy tests were found unreliable in a preliminary study involves two repeated measures. U19 cricket players did not perform game skills due to the physically and technically demanding nature of these tests and local cricket coaches' had reservations on U19 cricket players performing rugby-oriented technical skills

regional academy players and 129 U18 male school-level rugby players in England. Academy players recorded superior bench press values. Whether these results indicates preferable recruitment of physically stronger academy players or different strength and conditioning training practices between groups, the findings highlight the importance of upper-body muscular strength and emphasise the need for its regular training.

In the current study, elite rugby players had significantly higher 2 kg MBCT test scores compared to sub-elite and cricket players. These findings highlight the importance of muscular power development among sub-elite and potential rugby players aiming to play elite rugby. There is evidence supporting the discriminative ability of upper-body muscular power in rugby athletes of different playing abilities. For example, Till et al. [29] found significant differences in medicine ball throw distances between national and regional players in the U13 and U14 age categories. The national players representing higher-level rugby players had superior scores compared to the regional players.

Elite U19 rugby players had better 40 m speed test scores compared to sub-elite and non-rugby players. Additionally, there were meaningful ES differences between sub-elite and cricket players. These findings indicate that 40 m sprinting ability discriminates between playing levels. Hence, schoolboy rugby coaches need to implement and emphasise training strategies that maintain or maximise development of that quality especially for lower-level rugby athletes to realise elite status. However, it is unclear whether our findings suggest specialised 40 m speed training for the elite players or selection bias of players showing superior 40 m sprint abilities by schoolboy coaches in SESRL. Gabbett and Herzig [30] found contrasting results between U17 elite and sub-elite junior rugby league players. Population and sport differences could explain varied results. However, Jones et al. [13] found differences in 40 m speed test between the professional academy U18 rugby players and school-aged rugby players indicating differences in playing abilities.

Elite U19 rugby players performed significantly better on RHIE test compared to sub-elite players. These findings are expected, as the standard of rugby increases, the intensity and competitiveness increases resulting in frequent high-intensity sprinting, tackling and scrummaging episodes [31]. Gabbett [32] showed that U17 division one players engaged in more repeated high-intensity effort bouts than division three players. Depending on position, the RHIE test assesses player performance abilities on repeated sprinting, tackling and/or scrummaging facilitating understanding of physical fitness, anaerobic capacity and fatigue tolerance levels [33]. As such, elite U19 male adolescent rugby players in the present study could be highly anaerobically trained or have optimal physical fitness to tolerate match-play demands, and recover better from competition demands compared to sub-elite. Match success in rugby has been attributed to team performance on these short and repetitive high-intensity activities [34, 35]. Accordingly, the ability to intermittently engage in repeated high-intensity efforts with minimal fatigue interference should be an important attribute to train in schoolboy rugby players. However, no studies have evaluated performances of U19 schoolboy rugby players using the RHIE test. Future studies investigating the discriminative ability of RHIE test are warranted. However, it suffices to suggest for improved conditioning of sub-elite rugby athletes with regards to RHIE performance ability for the attainment of elite status in schoolboy rugby.

The present study showed that elite and sub-elite rugby players were similar in body mass and aerobic endurance but superior to non-rugby players. The lack of differences between rugby players probably suggest to the overall importance of prolonged high-intensity intermittent running ability and body mass in rugby much more than in cricket. Reportedly, rugby is a well-known high intensity, intermittent contact sport characterised by high-intensity sprints interspersed with tackles, rucks, mauls and scrums [36–38]. The present study findings align with previous studies conducted among older adolescent RU and rugby league players [13, 39–41]. Considering the physical nature of RU and the need to generate greater impact forces in collision activities, increased body size and aerobic fitness are advantageous qualities for rugby than cricket players [5, 36, 37].

Tackling proficiency and catching ability tests failed to differentiate elite from sub-elite players. However, elites had greater passing ability compared to sub-elites. This provides support for use of passing ability test for assessing playing ability in U19 schoolboy rugby. Lack of differences for tackling and catching probably emphasise the importance of these skills to the overall sport of rugby regardless of playing standard. Tackling proficiency in rugby has been related to match success [42, 43]. Consistently, Gabbett et al. [44] showed that catching and tackling skills were similar among first, second and third grade rugby league players. However, passing significantly separated first from third grade players. In contrast, Gabbett et al. [39] showed large ES differences between junior elite and sub-elite rugby players for tackling proficiency. Methodological, population and sport differences between studies could explain discordant results. In the latter study, tackling was evaluated based on technical criteria with six elements. The present study modified the criteria and had 10 items.

Limitations

Although this study advances research on attributes defining good U19 rugby players, it is not without limitations.

i. The cross-sectional nature of the study lacked analysis over an extended period of time [45]. This design fails to consider the dynamic nature of player development possibly narrowing the usefulness of the data for TID [46].
ii. Although the novel element of this study entailed investigating SCRuM test items ability to differentiate between playing standards, one school was conveniently-selected to represent each U19 playing standard. This limits the external validity of study results to other schools and age-categories.
iii. The groups were tested at different phases of their respective seasons resulting in differences in training and competition exposure across playing standards.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s13104-019-4563-y.

Additional file 1. Order of the SCRuM tests performed during test–retest reliability study and subsequent studies testing rugby and cricket players.

Additional file 2. The SCRuM test battery.

Additional file 3. Results for intraclass correlation coefficient, coefficient of variation, smallest detectable change, and limits of agreement for the SCRuM test items.

Abbreviations

CESRL: co-educational School Rugby League; CV: coefficient of variation; CI: confidence interval; ES: effect size; ICC: intraclass correlation coefficient; LoA: limits of agreement; 2 kg MBCT: 2 kg medicine ball chest throw; 1RM BP: one repetition maximum bench press; 1RM BS: one repetition maximum back squat; RHIE: repeated high intensity exercise; SEM: standard error of measurement; SESRL: Super Eight School Rugby League; SCRuM: School Clinical Rugby Measure; SD: standard deviation; SDC: smallest detectable change; SKF: skinfolds; SR: Sit and Reach test; TID: talent identification; U: under; VJ: vertical jump test; WSLS: wall sit leg strength test; Yo: Yo IRT L1-Yo–Yo intermittent recovery test level 1.

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Authors' contributions

MC, BCM and GF originally developed the concept and design of the study. MC is a doctoral student at UCT and this manuscript is part of his doctoral thesis. MC acted as the lead investigator under the guidance, mentorship and supervision of BCM and GF. MC conducted the literature review, recruited and trained research assistants and participants with variable assistance coming from other people who were acknowledged in the acknowledgment section. MC supervised the data collection. MC drafted the manuscript for publication and acted as the corresponding author. BCM and GF performed critical revision of the manuscript, statistical input, and provided extensive revisions prior to submission to the journal for review. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to the fact that the data is part of ongoing research. However, the data are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study adhered to guiding ethical principles under the Declaration of Helsinki. Institutional access and permission to conduct the study at the schools was obtained from Ministry of Primary and Secondary Education (Ref C/426/3), Harare Province Education Director Office, and from the respective school headmasters of the three schools involved in the study. Ethical approval was sought and granted by the Human Research Ethics Committee (HREC) of the University of Cape Town (Ref: 016/2016) and, locally from Medical Research Council of Zimbabwe (Ref: MRCZ/A/2070) since the study was conducted in Zimbabwe. Participants provided written informed assent prior to participation following verbal explanations and reading of information letters explaining the study rationale and all procedural issues regarding the study. Parents provided written informed consent allowing their child to participate in the study.

Consent for publication
Not applicable as the manuscript does not contain any data from any individual person.

Competing interests
The authors declare that they have no competing interests.

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Publisher's Note

11 SUPPLEMENTARY INFORMATION

Supplementary file 1: Data on effect sizes and smallest detectable change for U19s athletes

Variable	Elite [1] (n=41)	Sub-elite [2] (n=46)	Non-Rugby [3] (n=21)	[1] vs [2] ES	[1] vs [3] ES	[2] vs [3] ES	§SDC [95% CI]
	Mean±SD	Mean±SD	Mean±SD	*d*	*d*	*d*	
Anthropometric tests							
Body mass (kg)	77.5± 9.58	75.9± 11.6	68.5±9.47	0.15	0.94†	0.70†	0.52 [0.39-0.78]
Height (m)	1.73± 0.06	1.72± 0.08	1.71±0.06	0.14	0.33	0.14	-
Biceps (mm)	6.71± 3.62	6.60± 3.14	6.57± 2.27	0.03	0.05	0.01	-
Triceps (mm)	9.44± 2.95	9.83± 4.58	8.36 ±2.69	0.10	0.38	0.39	-
Subscapular (mm)^{wg}	12.8± 2.74	13.5 ±4.64	11.2 ±2.64	0.18	0.59	0.61†	1.53[0.43-1.79]
Suprailiac (mm)	8.93 ±3.84	9.51 ±3.93	9.52 ±1.98	0.15	0.19	0.00	-
Abdomen (mm)^{w}	11.4 ±2.85	13.3 ±5.90	11.8± 2.41	0.45	0.15	0.33	-
Thigh (mm)	9.98± 2.48	11.0 ±4.83	9.08 ±2.00	0.27	0.40	0.52	-
Calf (mm)^{w}	5.49 ±1.03	6.11 ±2.07	6.17 ±1.29	0.38	0.58	0.03	-
Sum of skinfolds (mm)^{w}	64.7 ±15.6	69.8± 24.4	62.7± 11.6	0.25	0.15	0.37	-
Physiological tests							
20m speed (s)	3.25± 0.17	3.36± 0.23$^{\alpha}$	3.47 ±0.25	0.54	1.03†	0.46	0.16 [0.08-0.24]
40m speed (s)	5.60 ±0.29	5.84 ±0.40$^{\alpha}$	6.10 ±0.27	0.69†	1.78†	0.76†	0.15 [0.08-0.21]
L-run test (s)	6.21 ±0.32	6.33 ±0.33$^{\alpha}$	6.43 ±0.25	0.37	0.77†	0.34	0.30 [0.19-0.37]
Vertical Jump test (cm)	47.8± 3.81	42.5± 3.84$^{\alpha}$	44.4± 3.85	1.39†	0.89†	0.49	2.70 [1.90-3.46]
2kg MBCT (m)	9.23 ±1.26	8.31± 1.18	7.18 ±1.16	0.75†	1.69†	0.97†	1.16 [0.98-1.27]
60s Push Up (n)	49.7 ±9.97	43.9 ±12.0	38.2± 6.50	0.53	1.37†	0.59	7.17 [6.07-7.98]
WSLS test (s)^{wg}	146.0± 9.72	137.5 ±21.7	132.6 ±7.41	0.51	1.55†	0.30	8.05 [6.78-9.34]
1RM BS (kg)	98.4 ±14.8	89.5± 16.3	-	0.57	-	-	-
1RM BP (kg)	90.5± 16.4	80.6 ±15.9	-	0.61†	-	-	6.64 [5.67-7.12]
RHIE (s)	39.3 ±2.96	41.9 ±2.97$^{\alpha}$	-	0.88†	-	-	3.55 [3.34-3.98]
Yo-Yo IRT(m)^{wg}	1505.9±75.8	1443.6±259.1$^{\alpha}$	1053.3±148.8	0.33	3.83†	1.85†	118.87 [101.1-137.9]
Rugby-specific tests							

Tackling test (%)	87.9± 8.44	84.8 ±8.16	-	0.37	-	-	-
Passing ability (au)^{wg}	116.2 ±2.13	113.0 ±4.07	-	0.99†	-	-	2.71 [2.01-3.14]
Catching ability (au)^{wg}	74.0 ±1.07	73.5± 1.35	-	0.41	-	-	-

[1]= Elite group; [2] =Sub-elite group; [3] =Non-rugby group; catching ability=running and catching ability test; SD= standard deviation; F= F test for ANOVA reporting the p value; wg= Welch F test reported and Games Howell test used for the post hoc analysis; w=Welch test results; SDC= Smallest detectable change with 95% CI; †moderate to large Cohen's d effect size (moderate effect: 0.6-1.2; large effect > 1.2); § =represents that the SDCs were only given for test items with moderate and large effect size as opposed to small and trivial; ES=effect size; 2kg MBCT=2kg medicine ball chest throw test; WSLS=Wall sit leg strength test; Yo-Yo IRT= Yo-Yo intermittent recovery test; Tackling proficiency (%) =Tackling test expressed as a percentage; 1RM =one repetition maximum; 1RM BS and BP= one repetition maximum bench squat and press respectively; RHIE=repeated high intensity exercise test measured in seconds; au =arbitrary units; VJ test=vertical jump test; α=sample size was 44 for the specified running tests; b= t-test independent samples test results comparing two groups; c=sample size was 26 for the respective tests; ES=effect size; One-way ANOVA=one way analysis of variance; *=significant p values for the ANOVA F test

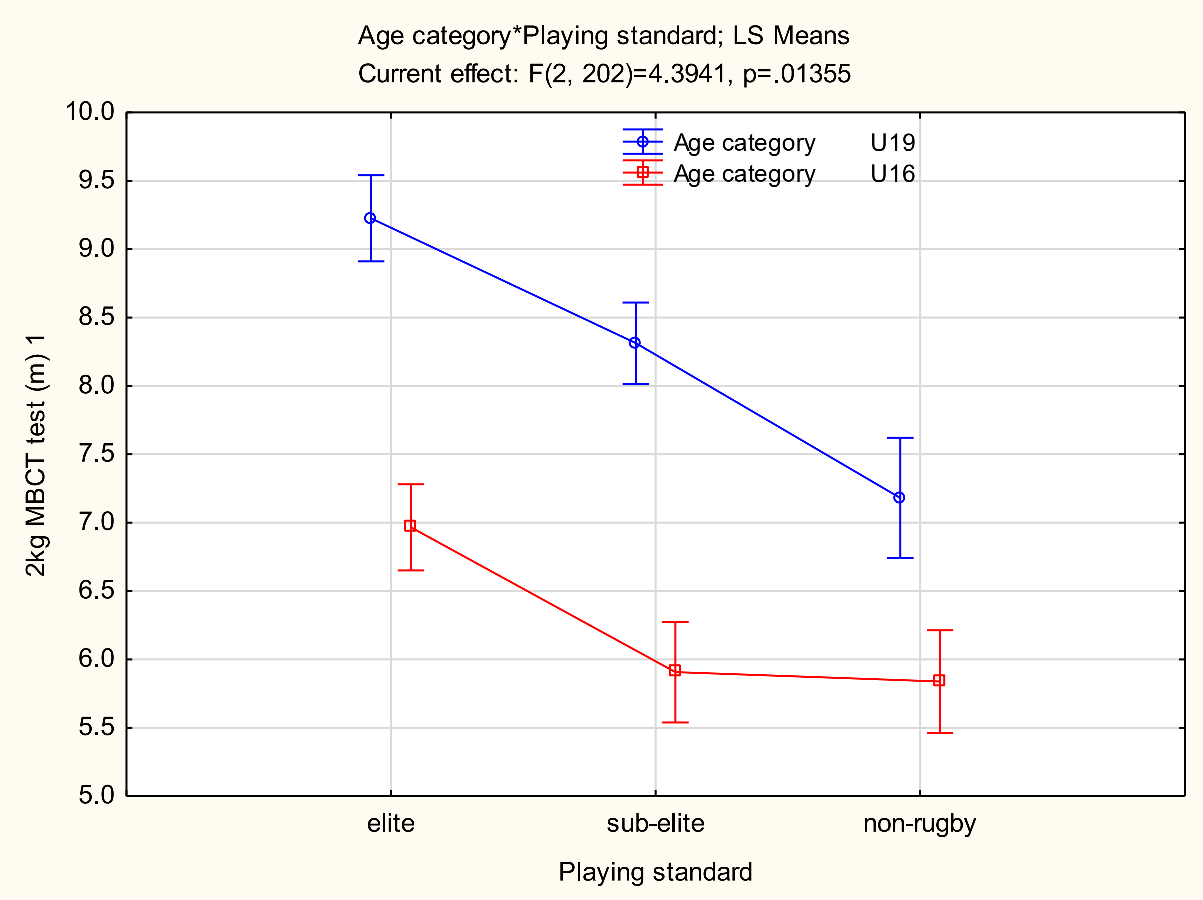
Supplementary file 2: Data for U16s on effect size and smallest detectable change

Variable	Elite [1] (n=41)	Sub-Elite [2] (n=30)	Non-Rugby [3] (n=29)	[1] vs [2]	[1] vs [3]	[2] vs [3]	[§]SDC [95% CI]
	Mean±SD	Mean±SD	Mean±SD	ES	ES	ES	
Anthropometrics							
Body mass (kg)	63.7 ±9.09	61.2 ±15.5	56.1± 7.83	0.20	0.90†	0.42	1.19 [0.76-1.5]
Height (m)	1.67± 0.08	1.68 ±0.08	1.66 ±0.08	0.13	0.13	0.25	-
Biceps (mm)	5.78 ±1.70	6.64 ±1.14	7.00± 3.91	0.59	0.40	0.13	-
Triceps (mm)	9.85 ±3.25	9.86 ±1.94	10.8± 5.89	0.00	0.20	0.21	-
Subscapular (mm)	10.9 ±2.86	11.3± 2.70	12.5± 6.21	0.14	0.33	0.25	-
Suprailiac (mm)	8.28± 2.97	8.90± 2.99	9.97± 5.46	0.21	0.38	0.24	-
Abdomen (mm)	11.4± 4.51	12.6 ±2.86	12.4± 6.34	0.32	0.18	0.04	-
Thigh (mm)	10.7 ±3.84	11.4 ±2.29	11.7 ±4.40	0.22	0.24	0.09	-
Calf (mm)	6.49 ±1.55	7.72± 1.17	7.73 ±3.48	0.90†	0.46	0.00	0.55[0.43-1.79]
Sum of SKF (mm)	63.4 ±17.1	68.4± 10.5	72.1± 33.1	0.35	0.33	0.15	-
Physiological tests							
10m speed (s)[a]	2.19±0.14	2.24±0.16	2.33±0.19	0.33	0.84†	0.51	0.14 [0.08-0.25]
20m speed (s)[a]	3.50 ±0.22	3.55± 0.22	3.63± 0.24	0.23	0.56	0.35	-
40m speed (s)[a]	6.14 ±0.46	6.20 ±0.60	6.47± 0.47	0.11	0.71†	0.50	0.19 [0.14-0.25]
L-run test (s)[a]	6.49 ±0.34	6.62± 0.46	6.67± 0.27	0.32	0.59	0.13	-
VJ test (cm)[wg]	38.3 ±2.38	34.9 ±2.82	32.6± 4.12	1.30†	1.69†	0.65†	2.33 [1.37-2.67]
SR (cm)[wg]	6.12±5.10	5.05±4.57	8.56±2.01	0.22	0.63†	0.99†	0.80 [0.67-1.26]
2kg MBCT (m)[wg]	6.97± 0.64	5.91 ±0.86	5.83± 0.86	1.40†	1.50†	0.09	0.28 [0.16-0.75]
60s Push Up (n)	38.4 ±10.1	35.6 ±8.90	32.6± 7.06	0.29	0.67†	0.37	3.05 [2.09-3.98]
WSLS (s)[wg]	132.1± 6.61	123.3 ±13.0	121.2 ±23.0	0.85†	0.64†	0.11	11.5 [7.12-13.6]
Yo-Yo (m)[wg]	1307.3±228.6	1030.7±269.6	897.9±171.7	1.11†	2.03†	0.59	106.4 [98.6-111.3]
Game skills							
Tackling test (%)	83.0± 8.87	68.3±7.94	-	1.75†	-	-	11.78 [8.34-12.67]
Passing test (au)	105.9± 4.86	104.7±4.34	-	0.26	-	-	-

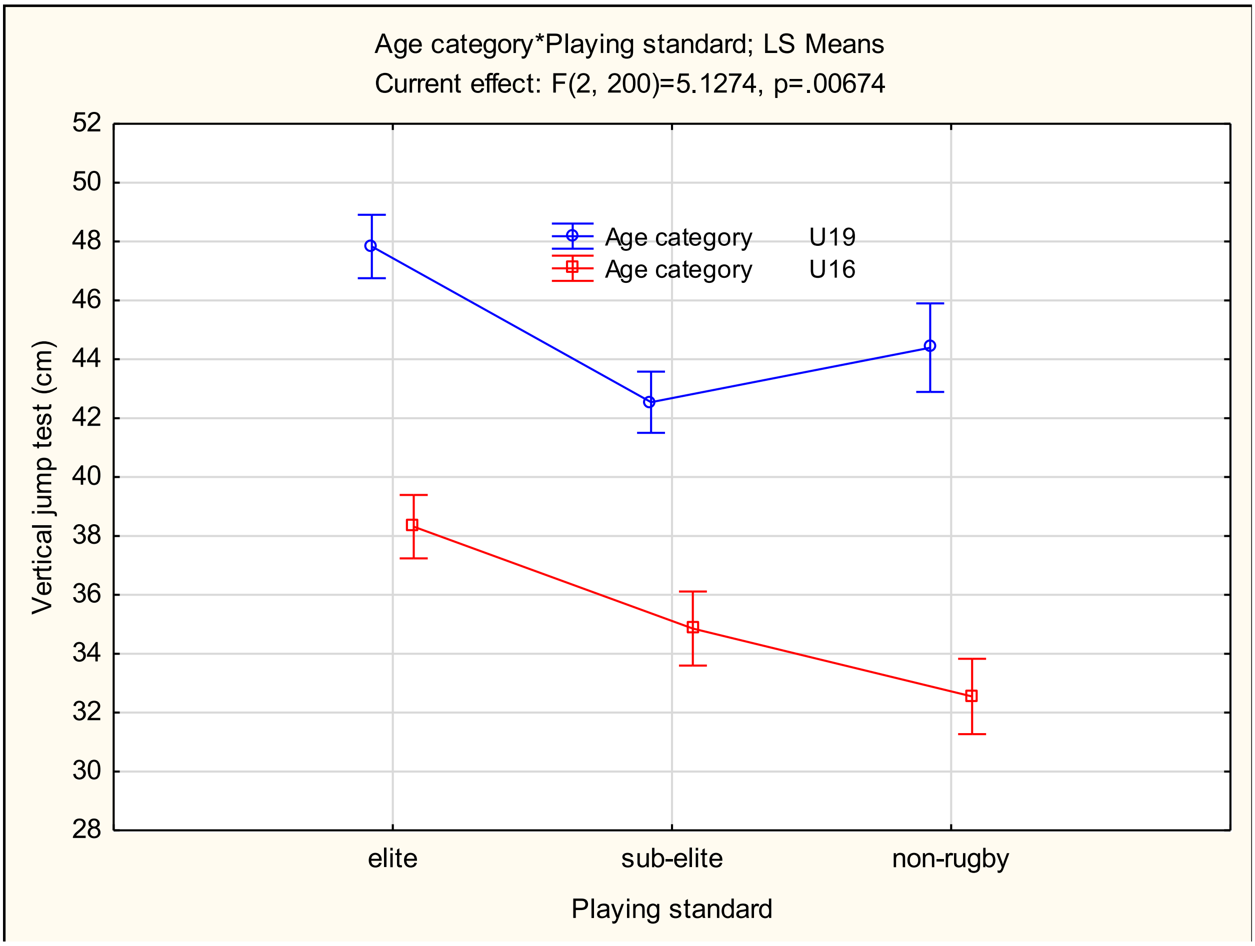
Catching test (au)	71.7± 2.06	68.3± 2.56	-	1.46†	-	-	8.79 [7.12-9.34]

[1]=Elite; [2] =Sub-elite; [3] =Non-rugby; catching ability=running-and-catching ability test; SD= standard deviation; F= F test for ANOVA reporting the p value; wg= Welch F test reported and Games Howell test used for the post hoc analysis; Tackling proficiency (%) =Tackling proficiency test expressed as a percentage; [a]sample size was 26 for the sub-elite rugby players who performed these tests; [b]t-test results for between two groups comparisons; †moderate to large Cohen's *d* effect size (moderate effect: 0.6-1.2; large effect > 1.2); SDC=smallest detectable change; §=The SDCs are only shown where there was a moderate or large effect size and omitted where was a small or trivial effect size. ES=effect size

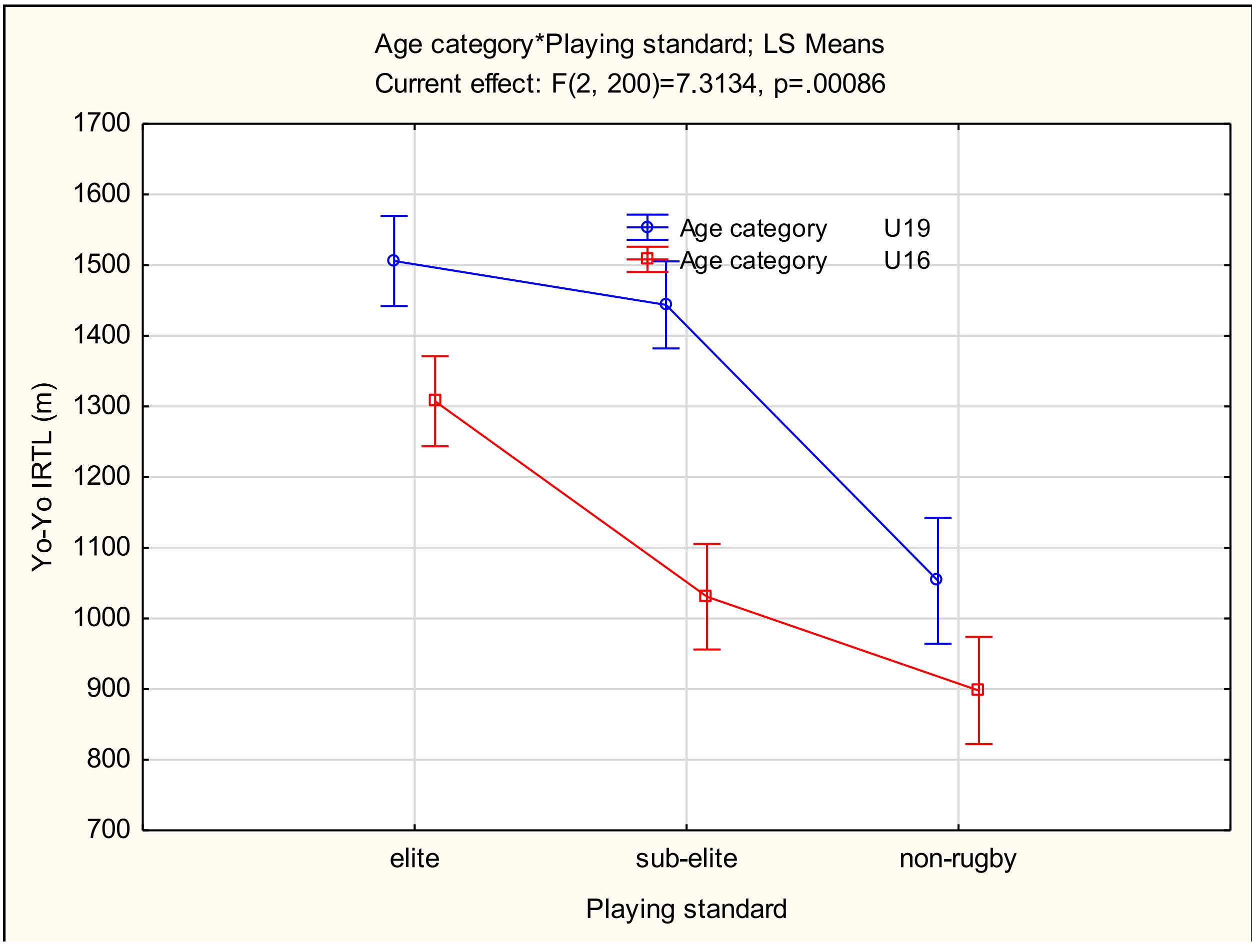
Supplementary file 3: Interaction plots



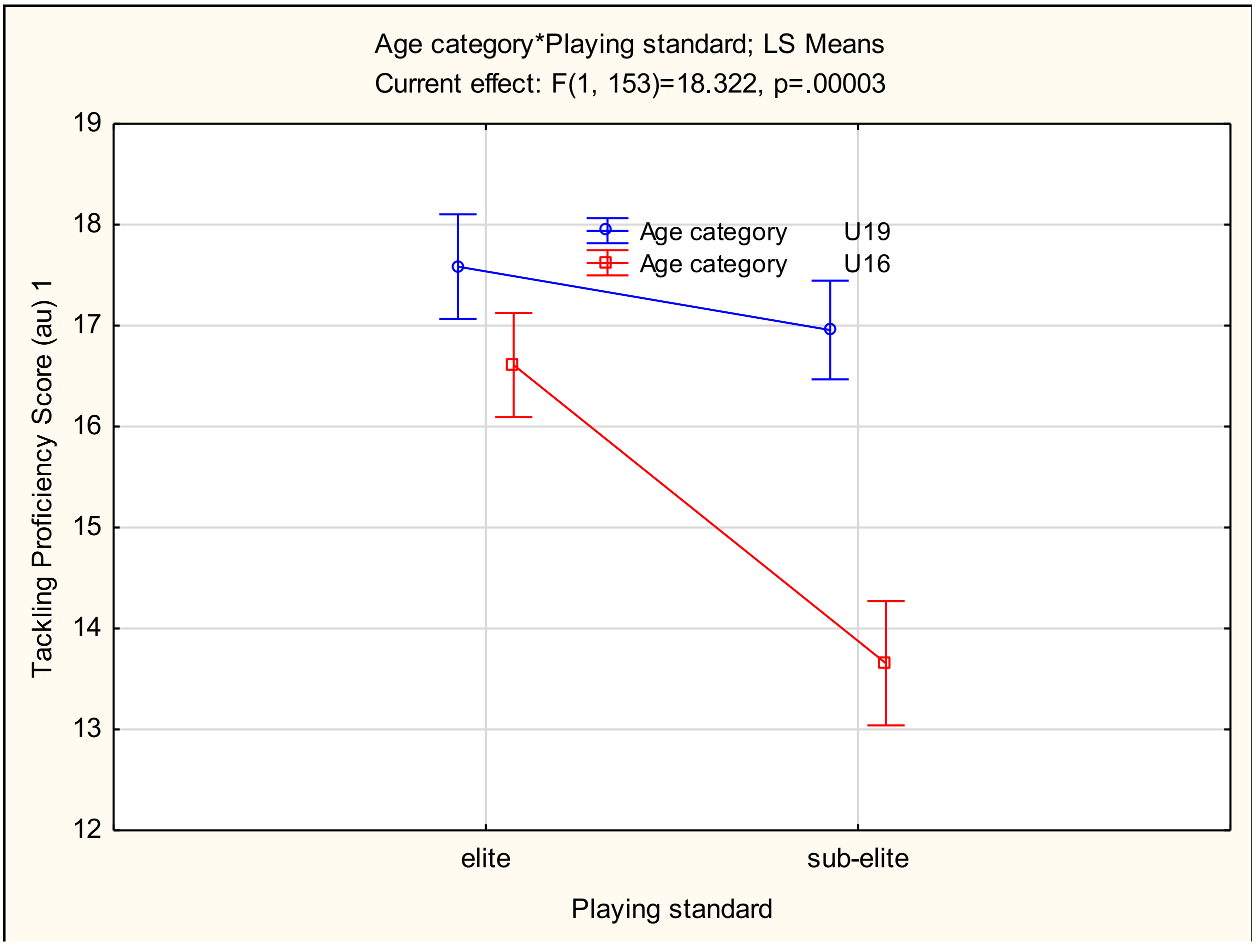
Comparison of 2kg medicine ball chest throws across playing standards for each age category. There were significant mean differences ($p<0.05$) in test scores between the U19s and U16 for elite, sub-elite and non-rugby. For U16s, 2kg MBCT test showed good discriminative validity in differentiating elite from both sub-elite and non-rugby players but failed to distinguish sub-elite from non-rugby players. At U19 level, elite rugby players were significantly better than both sub-elite and non-rugby players, and sub-elite were also significantly better from non-rugby players. The largest mean differences between age categories were among the elite and sub-elite.



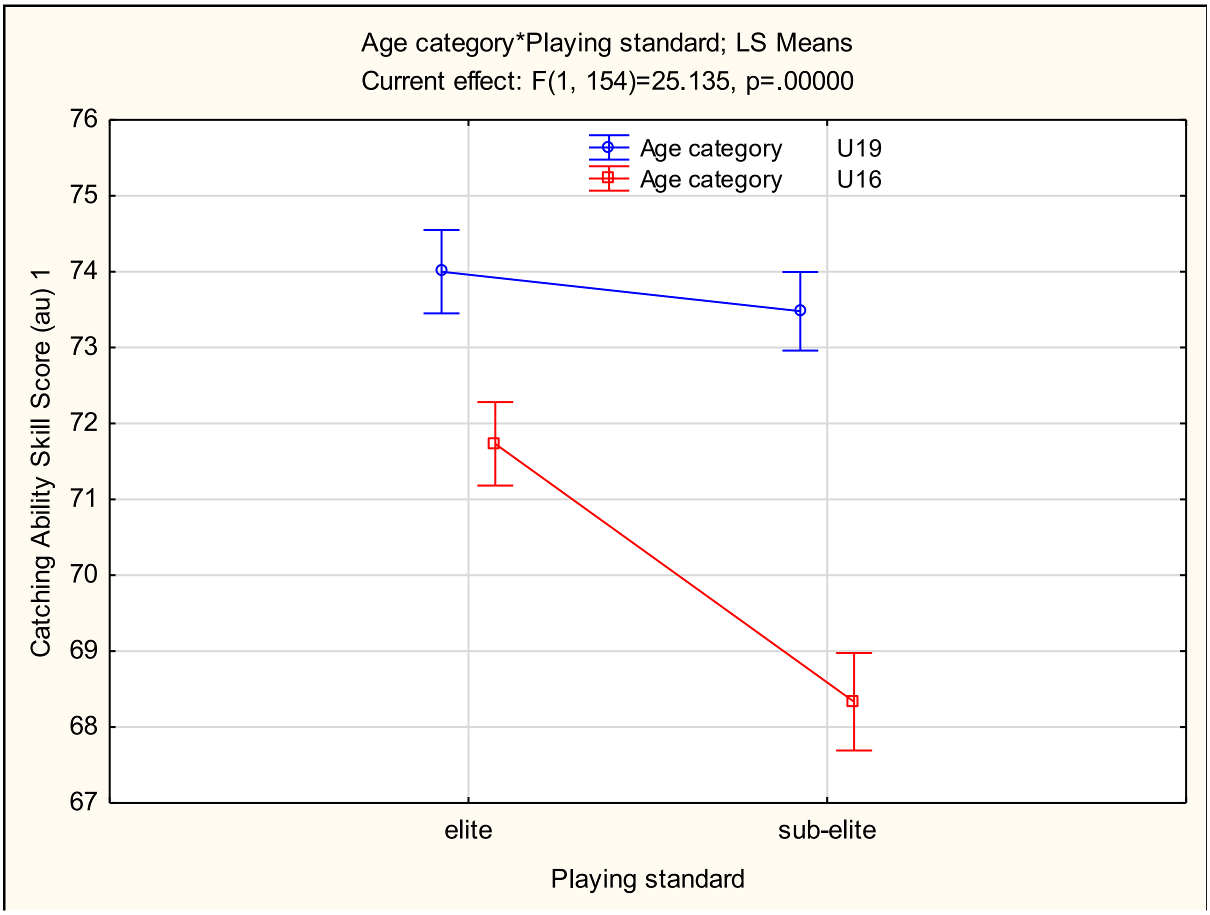
Vertical jump test effectively discriminated elite from both sub-elite and non-rugby players and concomitantly sub-elite from non-rugby players at U16 level. However, at U19 level, non-rugby players showed similar test scores to sub-elite rugby players. The largest mean differences between age categories were among the non-rugby players ($p<0.05$; $\eta^2_p=0.43$).



A comparison of Yo-Yo intermittent recovery test scores across playing standards for the two age-categories. The Yo-Yo IRT L1 test scores significantly improved with increasing playing standard among U16s but failed to distinguish elite from sub-elite rugby players at U19 level. The sub-elite rugby players showed the largest mean differences between U19 and U16 athletes ($p<0.05$; $\eta^2_p=0.26$).



Elite rugby players significantly outperformed sub-elite rugby players at U16 level and at U19 level there were no significant differences in tackling proficiency scores. The sub-elite rugby players showed the largest mean differences between the age categories.



Running-and-catching ability scores compared across playing standards for the U19 and U19 athletes. Elite rugby players outperformed sub-elite rugby players at U16 level and at U19 level there were no significant differences. Greater mean changes between U19 and U16 were among sub-elite rugby players relative to the elite players.