

**THE AGREEMENT, RELIABILITY AND ACCURACY OF A SUBJECTIVE-RATING
FOR TECHNIQUE MEASUREMENT IN RUGBY UNION AFTER VIDEO-BASED
TRAINING**

To be submitted in fulfilment of the MSc degree in Exercise Science

by

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LIST OF ABBREVIATIONS

CV – Coefficient of Variation

ES – Effect Size

ICC – Intraclass Correlation Coefficient

HREC REF – Human Research Ethics Committee reference number

IFT – Intermittent Fitness Test

K – Kappa

LoA – Limits of Agreement

MAS – Mean Aerobic Speed

MSFT – Multi-Stage Fitness Test

obs – Observations

P_o – Proportion of observed agreement

P_c – Proportion of chance agreement

RM – Rep Max

ROC – Receiver Operator Characteristics

RSA – Repeat Sprint Ability

SAC – Scientific Advisory Committee

SEM – Standard Error of Measurement

TEM – Technical Error of Measurement

TT – Time Trial

V0-4 – Visits 0 to 4

V_{crit} – Critical velocity

VO_{2max} – maximum volume of oxygen consumed

VO_{2peak} – maximum volume of oxygen consumed at a point in time

YoYo1 – Yo-Yo intermittent endurance test level 1

YoYo2 – Yo-Yo intermittent endurance test level 2

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ABSTRACT

Background: Rugby union is a high-intensity, intermittent sport, characterised by numerous contact events, such as rucks, mauls, scrums, and tackles. Specifically, the tackle is the most common action to occur during a rugby game. Subsequently, the tackle (tackler and ball-carrier) is responsible for the highest number of total injuries during a season. The most effective tackle technique is associated with a lower risk of injury than poorly executed tackles. Considering the prevalence of tackles, their propensity to cause injury, and the link between safety and proper tackle technique, a tool for assessing individual tackling and ball-carrying technique would be useful for rugby union researchers and practitioners. In particular, the assessment of tackling and ball-carrying technique would aid in monitoring adaptations to training, evaluating training programs and the prescription of training, assessing player qualities, and predicting performance and identifying future talent.

Objectives: The primary objectives of this study were 1) to determine if undergoing video-based training would improve the agreement, reliability, and accuracy of raters using a subjective-rating measure to assess contact technique in rugby union, and 2) to establish if a self-selected viewing pace resulted in improved agreement, reliability, and criterion-validity over a real-time pace.

Methods: Data were collected from 30 participants, with no prior experience in rugby union, who were randomly divided into training and non-training groups. After completing the training or non-training visits, all participants conducted tackling and ball-carrying technique assessments in 4 subsequent visits. Participants viewed video footage of players tackling and carrying the ball into contact during a full contact rugby drill on a laptop computer. Participants assessed tackling and ball-carrying technique using the standardised list of technical criteria. Technical proficiency scores were calculated out of 12 for tackling technique and out of 10 for ball-carrying technique, respectively. Agreement and reliability of the assessments were measured using the proportion of observed agreement (P_o) and Kappa statistics (K). Criterion

validity (accuracy) was measured using the proportion of observed agreement (P_o) by comparing the raters' assessments to a criterion. Between groups comparisons for technical proficiency scores and accuracy were done with hypothesis testing and effect sizes.

Results: Over the real-time and self-selected paces, the training group produced 61-73% ($K=0.24-0.38$, Fair) and 63-73% ($K=0.12-0.17$, Poor) inter-rater agreement for tackling and ball-carrying technique, respectively. The non-training group produced 61-72% ($K=0.26-0.38$, Fair) and 59-71% ($K=0.15-0.19$, Poor) inter-rater agreement for tackling and ball-carrying technique, respectively. Including both real-time and self-selected paces, the within session intra-rater agreement for the training group ranged from 71-84% ($K=0.43-0.65$, Moderate-Substantial) and 74-83% ($K=0.39-0.48$, Moderate) for tackling and ball-carrying technique assessment, respectively. Then, the intra-rater agreement for the non-training group ranged from 68-83% ($K=0.40-0.62$, Fair-Moderate) and 67-84% ($K=0.31-0.55$, Fair-Moderate) for tackling and ball-carrying technique assessment, respectively. In terms of between session reliability, over the real-time and self-selected paces, the training group achieved intra-rater reliability that ranged from 74-83% ($K=0.50-0.62$, Moderate-Substantial) and 72-82% ($K=0.35-0.45$, Fair-Moderate) for tackling and ball-carrying technique assessment, respectively. The non-training group achieved intra-rater reliability ranging from 72-82% ($K=0.46-0.59$, Moderate) and 69-81% ($K=0.33-0.48$, Fair-Moderate) for tackling and ball-carrying technique assessment, respectively. The technical proficiency scores between the groups displayed variation, and in some cases it was statistically significant. Compared to the criterion scores, the training group produced observed agreement of 68% and 67% for real-time pace and 74% and 72% for self-selected pace on tackling and ball-carrying technique assessment, respectively. The non-training group produced observed agreement of 66% and 67% for real-time pace and 74% and 73% for self-selected pace on tackling and ball-carrying technique assessment, respectively.

Conclusion: Whether trained or untrained, the individual should be able to produce the same results if the footage is assessed within the same viewing period (agreement) or over two

separate viewings (reliability). The tool is accurate for both groups when assessing at real-time or self-selected paces, with the latter being more accurate. However, it would appear that the tool is insufficiently robust when it comes to agreement between different raters. Future research should explore the inter-rater dynamics of assessing tackling and ball-carrying technique.

Keywords: rugby union; tackle; ball-carry; subjective rating; reliability; agreement; accuracy

1. INTRODUCTION AND SCOPE

1.1 RUGBY UNION

A rugby union game is played over 80 minutes, divided into two 40 minute halves, with the objective to score more points than the opposition through *tries* (5 points), *conversions* (2 points), and *penalty goals* or *drop goals* (3 points). The game is characterised by intermittent and repeated periods of high-intensity activities, involving running, passing, kicking, and numerous contact events, such as rucks, mauls, scrums, and tackles¹⁻³. The tackle, involving both the tackler and the ball-carrier, is the most common event in the a game⁴. Depending on position, players can make an average of 11 tackles², and up to 30 tackles per game². Subsequently, the tackle is also responsible for the highest number of total injuries⁴⁻⁶. Higher incidence and severity of injuries is negatively linked with team success, and reductions of this injury burden can positively influence success in rugby union competitions⁷. Due to the relationship of the tackle (tackler and ball-carrier) with safety and performance, it is imperative to be able to measure and monitor the skill and technical competencies of rugby union players when tackling or carrying the ball into contact.

1.2. MEASUREMENT IN RUGBY UNION

Sport has evolved largely due to changes to competition structures and rules⁸⁻¹¹, science and technology¹²⁻¹⁴, and safety concerns^{11,15,16}. Rugby union is no different, with the major watershed moment coming after 1995 in the form of professionalism. However, the reality is that the aforementioned factors are secondary to economics as the primary driver for the evolution of sport¹⁰. Governing bodies and associations make affordances to increase offensive play and maintain healthy competitive balance, with the aim to improve appeal to fans and influence the capacity to generate revenue¹⁰. In the case of rugby union, professionalism and rule changes have instigated changes in several fundamental components of the game, such as increases in the number of rucks, passes, tackles, and tries scored¹⁷. In turn, rugby players have had to adapt to the game to remain competitive.

Olds (2001) likens sport to the Darwinian system of evolution, due to its competitive and selective nature. Essentially we are seeing “bigger and better” players^{15,19}. Concerning their findings of generally small correlations of rugby player physical characteristics to the variance found in game statistics, Smart et al. (2014) state, “*It is possible that selection pressures have removed those players who do not have physical characteristics that are close to the ideal by the time they reach provincial level.*” Research concerning the change in morphology of rugby union players over the past century suggests that as the “ideal” sporting body becomes increasingly rare, these individuals become a more sought after commodity¹⁸. In an editorial by Lambert (2011), the author describes the business principle of, “you cannot manage what you don’t measure” in relation to sport. With so much riding on the performance of a select few for brief periods of athletic performance, it becomes imperative to measure the changes in athletes in order to assess, predict, prescribe, and improve. Measurements attained from field and laboratory testing enable researchers and practitioners to monitor adaptations to training, evaluate training programs and the prescription of training, assess player qualities, and to predict performance and identify future talent²². As rugby players become somewhat more homogenous, measurement tools need to be substantiated to ensure the quality of measurements. It would be beneficial to consider whether testing and measurement in rugby union have been sufficient or of a high enough quality.

Numerous field and laboratory tests are concerned with sport performance and physiology, resulting in much redundancy of measurement tools²³. Despite the large selection of tests available to sport scientists, it is insufficient to simply be more deliberate about testing. Scientists and practitioners should determine the quality of the measurement tools they wish to use before making a decision. Impellizzeri & Marcora (2009) have proposed that the practice of clinimetrics should become more commonplace among researchers and practitioners to counteract the over-abundance of measuring tools and ensure the quality of measurements. Relevant to sport sciences, there are four important qualities to consider when selecting the measurement tool: 1) the conceptual model, 2) reliability and accuracy, 3) validity, and 4) responsiveness.

The **conceptual model** has been defined as, “the rationale for and description of the concepts and the populations that a measure is intended to assess and the relationship between those concepts”²⁵. A rationale more than a quality, it breaks the sport into the fundamental factors contributing to performance in the sport. **Reliability**, in its simplest form, refers to “the degree to which an instrument is free of random error”²⁵, whereas **accuracy** concerns the fraction or percentage of cases for which the rater or instrument is correct²⁶. Therefore, an instrument can be reliable, but inaccurate. **Validity**, taking many forms, is generally accepted to be the degree to which an instrument measures what it was intended to measure^{23,25,27}. **Responsiveness**, or sensitivity to change, refers to an instrument’s capacity to detect changes over time^{23,25}. Rugby union sport scientists should understand these qualities and decide if an instrument or measure will possess them before finalising their testing batteries. Measures should not be wantonly devised or used, but should be subjected to more intensive methods of development (if necessary) and validation to improve the quality of sport science research and its practical applications²⁴. A detailed review of clinimetrics for sport science is paramount to the understanding and correct usage of these concepts.

Rugby union continues to evolve and scientists and practitioners must endeavour to keep pace. It is necessary to establish a conceptual model for rugby union to better understand the factors contributing to performance. Once the conceptual model and relevant factors are established, it would be useful to review the measures and tests which pertain to the factors of rugby union performance, and ascertain which are regularly used in rugby union testing batteries.

This thesis is divided in 4 further chapters aiming to present information relevant to testing performance of rugby players. Clinimetric qualities are further explored in chapter 2. The concept of performance in rugby union is explored in chapter 3. The experimental study is described in chapter 4. Lastly, the final chapter consolidates the information as a discussion in chapter 5.

2. CLINIMETRICS

Clinimetrics pertains to standardized, quantitative methods of collecting, comparing, and analysing data²⁸. The principles of clinimetrics should be applied to evaluate the quality of an existing measurement tool or used when developing a new measurement tool. Originally devised for use by physicians due to a lack of standardized methods and procedures in the domain of clinical patient care²⁸, clinimetrics is considered to be a branch of biometrics (the measurement of biological phenomena)²³. While not directly concerned with clinical patient care procedures, sport science can benefit from the principles of clinimetrics.

Before developing a new measurement tool, one should establish the existence or availability of a tool which could meet testing requirements²³. Once it has been confirmed that there is no suitable measurement tool available, a new measurement tool can be developed with the use of clinimetrics. This process would reduce the production of redundant measurement tools²⁴.

An apparent lack of consensus on clinimetrics created a need for a scientific review process on guidelines for the selection and development of measurement tools and instruments. In 1994, the Scientific Advisory Committee (SAC) was formed by the Medical Outcomes Trust, to be an independent entity. Their goal was to review instruments and assess their suitability for general use by the trust²⁵. The SAC is predominantly concerned with reviewing tests or instruments within the domains of health status and quality of life²⁵. There are eight attributes on which the SAC focuses when reviewing measures or instruments; 1) the conceptual and measurement model, 2) reliability, 3) validity, 4) responsiveness, 5) Interpretation, 6) respondent and administrative burden, 7) alternative forms, and 8) cultural/language adaptations. The *conceptual and measurement model*, *reliability*, *validity*, and *responsiveness*, are considered most important when selecting an instrument for measuring physical performance²⁴. These attributes are described in the following sections.

2.1. CONCEPTUAL AND MEASUREMENT MODEL

The conceptual model has been defined as the rationale for and description of the concepts and the populations that a measure is intended to assess and the relationship between those concepts.²⁵ The conceptual model breaks the sport into fundamental factors contributing to performance in that sport. Impellizzeri & Marcora (2009) created a basic conceptual model for soccer performance, which was adapted to illustrate an example of a conceptual model (figure 1). In this instance, win/lose or league standings offer insight into performance, but it isn't possible to measure performance directly. It becomes necessary to deconstruct performance into contributing factors, which are further broken down into measurable attributes, such as agility or sprint ability²⁹. The measurement model concerns the tests used to measure the attributes, and has been defined as that which operationalizes the conceptual model and is reflected in an instrument's scale and subscale structure and the procedures followed to create scale and subscale scores.²⁵ The measurement model deals with the level of measurement (ordinal, interval, or ratio scales) and is often concerned with subjective measures and questionnaires²⁵.

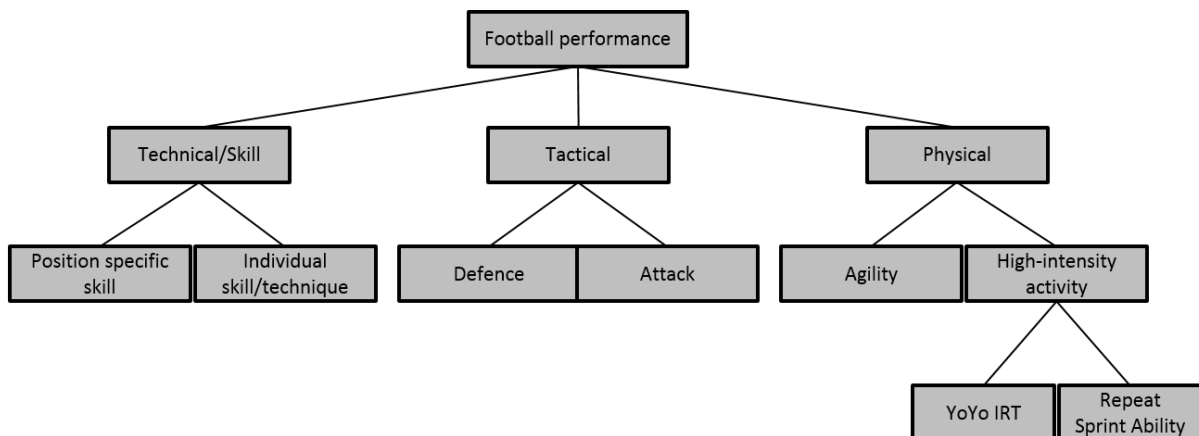


Figure 2.1: Conceptual model for soccer performance adapted from Impellizzeri & Marcora (2009).

2.2. RELIABILITY

Feinstein (1983) promotes reliability as the most important attribute to consider when determining the quality of an instrument. In the same line, de Vet *et al.* (2003b) state that an instrument with poor reliability is less valid because it will produce different outcomes at each measurement. Reliability should be tested first as an instrument cannot be valid if it has poor reliability²⁷.

'Reliability', 'Reproducibility', 'Consistency', 'Agreement', 'Concordance', and 'Stability' are terms often used interchangeably in the literature²⁷. The SAC (2002) has defined reliability as the degree to which an instrument is free from random error, and declare that (test-retest) reproducibility is another approach to reliability. Test-retest reproducibility is the degree to which an instrument yields the same results over a period in which the participants' qualities of interest aren't expected to have changed at all²⁵. de Vet *et al.* (2003b) define reproducibility as the extent to which repeated measures yield the same outcome, this is then comprised of reliability and agreement as separate concepts. Agreement concerns a lack of measurement error, while reliability concerns the extent to which individuals can be distinguished from one another, regardless of measurement errors^{23,30}. Atkinson & Nevill (1998) define reliability as the consistency of measurements, or of an individual's performance on a test, or the absence of measurement error. In Atkinson & Nevill (1998), Baumgartner is cited to have identified two forms of reliability; relative and absolute. Relative reliability pertains to the degree to which individuals maintain their position in a sample with repeated measurements, while absolute reliability deals with the degree of variation in repeated measures of individuals²⁷. Overall, the terminology is not conducive to effective communication, and for the sake of simplicity, reliability as defined by the SAC (2002) will be the operative term going forward (i.e. the degree to which an instrument is free from random error). A special case for the use of agreement for categorical variables is made in section 2.6.

Assessing reliability of an instrument with continuous variables requires the repetition of the measurement several times on a sufficiently sized sample³¹. Hopkins (2000) advocates the

use of within-subject variation, change in the mean, and retest correlation as the most important ways of representing reliability. Within-subject variation can be quantified with the Standard Error of Measurement (SEM), which is derived from the standard deviation of the individual's scores on several trials³¹. SEM can be manipulated to represent a relative score as a Coefficient of Variation (CV) score as a percentage of the mean³¹. Particular to sport sciences, relative and absolute reliability should be statistically analysed using the Intraclass Correlation Coefficient (ICC) and SEM (and/or CV), respectively^{24,27,32}. The use of ICC and SEM as statistical representations of reliability is further advocated by Hopkins et al. (2009). Bland and Altman (1999) advocate 95% Limits of Agreement (LoA) as an alternative method for assessing the absolute reliability of a measure. This method calculates the range within which 95% of the differences between the two numerical measurements occur.

2.2.1. THE KAPPA COEFFICIENT

Introduced by Cohen (1960), the Kappa Coefficient is an index for rater agreement on categorical variables. It has since become widely used when analysing data from the medical and health sciences. In sport science research, Kappa has been used to measure the reliability, or more accurately the agreement, of researchers conducting video analysis studies³⁵⁻³⁷ and skill assessment studies³⁸. Along with the popularity of Kappa, has come discussion about its appropriateness, relevance and reporting practices³⁹⁻⁴⁶.

Though often used interchangeably, there is a difference between “agreement” and “reliability”^{43,47}. *Agreement* should refer to the extent to which observations are identical, whereas *reliability* should refer to the extent of variability and error inherent within the measure^{43,47}. This is pertinent in the case of the Kappa Coefficient, as categorical variables are not analysed with the traditional statistics used for measuring the reliability of continuous data.

Kappa is derived from the proportion of observed agreement (P_o) and the proportion of chance agreement (P_c), and is an index which represents the extent of agreement that can be

achieved beyond chance (eq. 1)^{42,43,48}. Kappa has been adapted to account for several situations which require different approaches to establishing rater agreement.

The most common and basic situation requires the use of Cohen's Kappa to determine true agreement between two raters making categorical ratings on players or participants. Weighted Kappa is an extension of Cohen's Kappa for use with ordinal variables⁴⁶. Fleiss, (1971) adapted Kappa for the measurement of agreement for multiple categorical variables, among any constant number of independent raters. The concepts of agreement and reliability, and the kappa statistics are relevant to the research described in chapter 4 because of the categorical nature of the data.

2.3. VALIDITY

Validity is generally accepted to be the degree to which an instrument measures what it was intended to measure^{23,25,27}. Thereafter, validity can take several forms, all of which are important but not always possible to achieve. *Criterion validity* is considered to be the most powerful type of validity, and pertains to an instrument being validated in relation to a criterion measure or 'gold standard'^{23,25}. *Construct validity* entails proving validity of an instrument against other instruments that claim to measure the same or similar hypothetical construct^{23,25,50}. Performance being a construct, allows researchers to use it as the construct against which to validate an instrument⁵¹. Continuing with the example of football, teams which are tested for skill may have the results compared to league position, and if higher skill correlates to a higher league position, then the measurement tool has construct validity. *Content validity* is a judgement of whether all the relevant components of a construct are measured by the instrument^{23,25}. Content validity is most often used in educational instruments which assess whether learning was achieved⁵⁰. *Ecological validity* appears to have been erroneously used in areas of academic literature, and has been confused with *representative design*⁵². *Representative design* concerns the extent to which conditions of a task are similar to the conditions which might be experienced in the task in reality⁵². *Ecological validity* refers to the relationship of a cue to an end state or outcome, (i.e. How important is the information

from this cue to the end goal?)⁵². Lastly, *logical validity* involves judging an instrument on face-value based on observation of its components²³.

Accuracy, a form of criterion validity, is an important attribute to consider when developing or evaluating a measurement tool, specifically those of a diagnostic nature. One might obtain reliable results, but these results might be reliably inaccurate. In regard to subjective rating measures, Engelhard (1996) defines accuracy as the match between ratings obtained from operational raters and those obtained from an expert panel on a set of benchmark performances. In simple terms, it is the fraction or percentage of cases for which the rater is correct (equation 1)²⁶.

$$Accuracy = \frac{No.correct\ decisions}{Total\ no.of\ cases} \text{ (equation 1)}$$

2.4. RESPONSIVENESS

Responsiveness, or sensitivity to change, refers to an instrument's capacity to detect changes over time^{23,25}. Responsiveness has been considered as somewhat redundant as a separate property in the presence of good reliability and validity⁵⁴. An instrument which is reliable and valid, would be sufficiently sensitive to measure any changes over time. Should an instrument have a small degree of measurement error, then it has test-retest reliability and, logically, is responsive enough to detect any changes over time. However, it might be wise to link responsiveness to an instrument's interpretation (discussed in section 2.5). For example, if an instrument is reliable but not responsive enough to distinguish small differences, then it may be unable to determine the degree of improvement of a player who scored 4 out of 5 on two separate occasions. Either the measurement tool is not responsive and did not register a change or the variable did not change. However, if this player had been scored on a different and more responsive scale with 10 items instead of five, it might have been that on the first occasion s/he scored 7 out of 10, and on the next occasion 9 out of 10. Due to the more responsive scale, it could then be interpreted that the player improved from one occasion to the next.

2.5. ADDITIONAL CLINIMETRIC ATTRIBUTES

The SAC (2002) have outlined several additional attributes that an instrument should have to be regarded as useful. *Interpretation* of an instrument concerns the degree to which one can ascribe meaning to the scores derived from the instrument²⁵. For example, should a participant score 7 on a 10-item instrument, one should be able to interpret the implications of that score within a specific context. For an instrument that is sufficiently responsive, it should be possible to interpret the meaning or significance of the difference between a score of seven and nine. In developing or evaluating an instrument, the *respondent* and *administrative burden* (time, effort, and other demands) should be considered²⁵. Two other attributes of a measurement tool that should be considered are; *alternative forms* and *cultural/language adaptations*. These two attributes concern the method of delivery (self-reported or administered forms, computer based, etc.) of the instrument and its efficacy of application across cultural and language barriers²⁵.

3. LITERATURE REVIEW

3.1. CONCEPTUAL MODEL FOR RUGBY UNION

The first step in developing a new test or measure for sport is to establish a conceptual model. This should encapsulate the factors contributing to performance in that sport²⁴. Rugby union is a complex team sport, with multiple factors and sub-factors contributing to performance. This necessitates the development of a conceptual model that can be reduced to measurable components²⁹. Figure 3.1 has been created to conceptualize the construct of performance in rugby union. It is important to distinguish between the factors and sub-factors contributing to performance, and their associated measurable components (e.g. Physical factor, speed sub-factor, 40m sprint test).

This conceptual model for rugby union uses the 4 primary factors (Physical, Psychological, Tactical, and Technical) proposed by Bompa & Haff (2009), and inserts sub-factors relevant to rugby union based on a review of the literature. In some instances reference will be made to rugby league, which is a sport with similar physical demands to rugby union. It is possible to use information and data from rugby league to make some inferences about rugby union. Within the review of the physical factor in rugby union, a systematic review was conducted as part of a bigger project. This part of the broader systematic review project concerned the tests and measures of speed, strength, and endurance commonly used in rugby union. Rugby-specific simulation tests were not included in these sections due to the multiple components that are measured simultaneously. Within the rugby-specific simulation tests the ultimate component being measured is performance on the test, but not necessarily the individual sub-factors or the corresponding components.

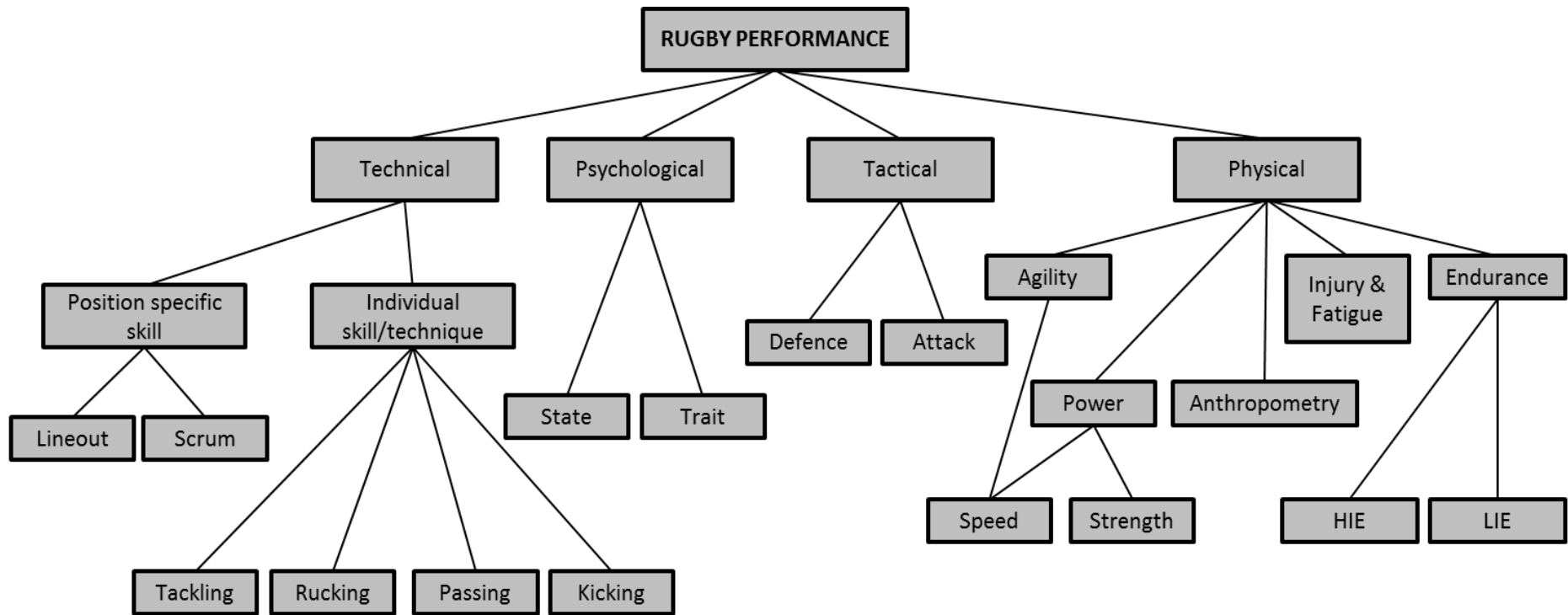


Figure 3.1: Conceptual model for performance in Rugby Union.

3.2. PHYSICAL

A plethora of attributes contribute to the physical component of rugby union. Duthie et al. (2003) describe the physical characteristics and capacities in a review of rugby union players. The physical characteristics of rugby union players are body mass, height, percentage body fat, and muscle fibre type²². The physical capacities of rugby union players are: maximal oxygen uptake (aerobic performance), anaerobic performance, muscle strength and power, and speed²². Interestingly, in this review agility of players was not included.

A review of sport science in rugby league by Johnston et al. (2014) divides the heading “Physical Qualities” into sub-headings such as: 1) body composition, 2) speed and acceleration, 3) agility, 4) muscular strength and power, 5) aerobic power, and 6) high-intensity running ability (anaerobic power). This is not to imply that the aforementioned factors are definitive; instead they could be in the list because they have been measured previously. When considered alongside skill, these physical factors are largely associated with selection and playing performance in professional rugby league players^{57,58}. Therefore, improved physical factors would be important considerations for rugby union.

As part of a broader project, a partial systematic literature review was conducted in conjunction with the primary supervisor to contribute towards a full systematic on the tests commonly used to measure physical performance of rugby players. The purpose of the review in this section is to establish the common tests of speed, strength, and endurance used in rugby union literature.

3.2.1. Methods

To ensure a thorough review of the literature, 3 data bases were accessed and researched: Scopus, Web of Science, and Pubmed. The primary search terms used were *rugby union*, *rugby union players*, and *rugby players*. Each of these primary search terms were associated with the terms *testing*, *measurement*, *assessment*, *speed*, *strength*, *aerobic*, *endurance*, and *running*.

Search results were combined and duplicates were removed. Thereafter, the results were reviewed at the title and abstract level before removing articles based on reviewing the full text. Finally, additional articles were added after cross-checking the tests used in the articles. At all but the last stage, the review process was intentionally more inclusive than exclusive, to reduce the chance of relevant articles being missed. Articles were included if they contained information about tests and measures of performance in rugby union, specifically concerning speed, strength, and endurance (aerobic and anaerobic). Articles were excluded if they were in a language other than English, or were conference posters or abstracts.

3.2.2. Results

The initial search results totalling 387, 823, and 748 articles were reduced to 43, 78, and 48 articles for speed, strength, and endurance, respectively (figure 3.2). After cross-checking the articles the final results of the systematic review were 57 articles for speed, 78 for strength, and 51 for endurance (figure 3.2).

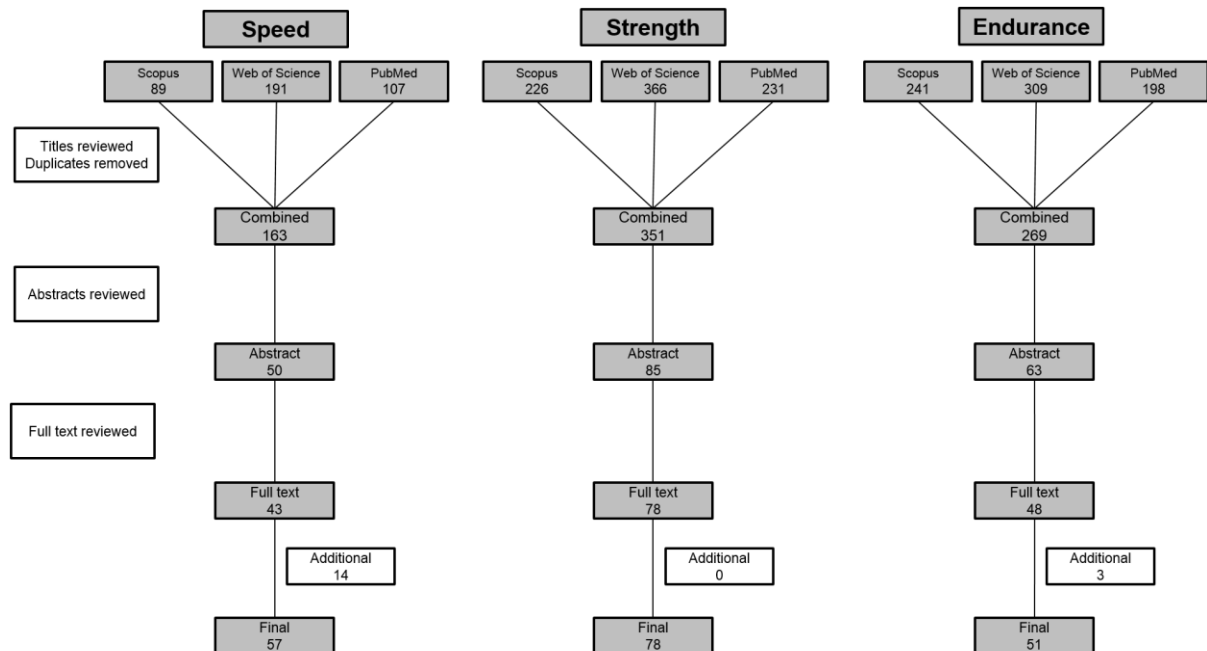


Figure 3.2: Flow chart of the process of the systematic review.

Speed

Table 3.1 contains the number of occurrences of tests of speed for rugby union within the reviewed literature. The 40m sprint was the most frequently used test of speed, followed by the 30m sprint. Timing gates were used in 45 out of 57 articles, making them the most commonly used measurement equipment. An unspecified starting position was the most common, occurring in 24 articles. Thereafter, a standing start position was the next most commonly reported, occurring in 20 articles. There were 26 and 11 articles reporting unspecified and indoor artificial surfaces, respectively.

Strength

Table 3.2 displays the results of the various strength tests used within the literature. General strength is the most common performance facet tested. The bench press and back squat, occurred in 32 and 24 articles respectively.

Endurance

Table 3.3 displays the breakdown of common tests of endurance in the literature. Aerobic tests (42) are more common than anaerobic tests (18). The most frequently used tests of aerobic and anaerobic endurance within the literature were the Multi-Stage Fitness Test (MSFT; 10) and Repeated Sprint Ability test (RSA; 10) respectively.

Table 3.1: Common methodologies for the assessment of speed in rugby union

| Test name | Reference | Reference |
|-------------------------|------------|-----------------------------|
| Equipment | | |
| Start position | | |
| Surface | | |
| 10m Sprint | 4 | 15&35m Sprints |
| Timing gates | | Timing gates |
| Crouched | | Standing |
| Unspecified | 2 59,60 | Indoor artificial |
| Self-selected | | Indoor artificial |
| Indoor artificial | 1 62 | 26m Sprint |
| Standing | | Timing gates |
| Unspecified | 1 63 | Crouched |
| 20m Sprint | 10 | Unspecified |
| Radar | | 40&110 yard dash |
| Standing | | Stop watch |
| Outdoor artificial | 1 65 | Unspecified |
| Timing gates | | Unspecified |
| Crouched | | 40m Sprint |
| Indoor artificial grass | 1 67 | Laser |
| Self-selected | | Crouched |
| Indoor artificial | 1 62 | Indoor artificial |
| Standing | | Indoor artificial |
| Grass | 3 20,69,70 | Stop watch |
| Indoor artificial grass | 1 67 | Standing |
| Unspecified | 2 72,73 | Outdoor artificial |
| Unspecified | | Timing gates |
| Indoor artificial | 1 75 | Crouched |
| 30m Sprint | 21 | Indoor artificial |
| Digital timer | | Indoor court surface |
| Unspecified | | Indoor court surface |
| Unspecified | 3 79–81 | Standing |
| Laser | | Indoor artificial |
| Crouched | | Unspecified |
| Indoor artificial | 1 68 | Unspecified |
| Standing | | Artificial grass |
| Indoor artificial | 1 94 | Grass |
| Radar | | Outdoor artificial |
| Standing | | Unspecified |
| Outdoor artificial | 1 65 | Unspecified |
| Timing gates | | Video analysis |
| Crouched | | Standing |
| flat outdoor | 2 96,97 | Unspecified |
| Indoor artificial | 1 99 | 50m Sprint |
| Standing | | Timing gates |
| Grass | 2 20,70 | Standing |
| Indoor artificial | 2 101,102 | Outdoor artificial |
| Outdoor artificial | 1 103 | Outdoor artificial |
| Unspecified | 1 105 | Unspecified |
| Unspecified | | 60m Sprint |
| Grass | 1 107 | Timing gates |
| Unspecified | 1 108 | Standing |
| Unspecified | | Outdoor artificial |
| Crouched | | Unspecified |
| Unspecified | 1 109 | Unspecified |
| Unspecified | | Unspecified |
| Unspecified | 3 110–112 | |

Table 3.2: Common methodologies for the assessment of strength in rugby union

| Facet | Reference | | Reference | |
|------------------------------|------------|-------------------------------|----------------------------------|-----------------------|
| Test name | | | | |
| Mode of testing | | | | |
| Details | | | | |
| Isokinetic Strength | 9 | | Strength | Cont. |
| Isokinetic Strength test | | | est. 1RM | |
| Biodex | | | Back squat | |
| Con ext knee & hip | 1 | 113 | 1-3reps | 1 102 |
| Con knee | 1 | 114 | 2-6reps | 2 70,115 |
| Ext & flex knee | 1 | 116 | 3-5reps | 1 62 |
| Con & ecc knee | 2 | 100,117 | 3reps | 4 60,93,94,118 |
| Con-trex dynamometer | | | Max reps (95% pred. 1RM) | 1 119 |
| Int/ext shoulder rotation | 1 | 120 | Bench press | |
| Cybex | | | 1-4reps | 3 121-123 |
| Con & ecc knee & hip | 1 | 61 | 2-4reps | 5 96,97,124-126 |
| Humac Norm dynamometer | | | 2-6reps | 2 20,70 |
| Con & ecc knee & hip | 2 | 127,128 | 3-5reps | 2 62,98 |
| Isometric Strength | 12 | | 5reps | 1 129 |
| 6sec pull | | | 6-10reps | 1 104 |
| Isometric Mid-Thigh Pull | 1 | 95 | Max reps (95% pred. 1RM) | 1 119 |
| Custom deadlift device | | | Bent-over row | |
| Deadlift | | | 1-3reps | 1 102 |
| 3 reps of Isometrics holds | 3 | 114,130,131 | Box squat | |
| Custom neck strength measure | | | 1-4reps | 3 121,123,132 |
| Custom head harness | | | 2-4reps | 6 96,97,124-126,133 |
| 3 reps of Isometrics holds | 8 | 134-141 | 2-6reps | 2 20,70 |
| Muscular endurance | 5 | | 5reps | 1 129 |
| 1min sit-ups | | | 6-10reps | 1 104 |
| Sit-ups | | | Chin-ups | |
| max reps | 1 | 142 | 2-4reps | 1 97 |
| Max reps | | | 2-6reps | 2 20,70 |
| Bench press | | | 6-10reps | 1 104 |
| max reps on 75%1RM | 1 | 143 | Deadlift | |
| Front squat | | | 1-3reps | 1 102 |
| max reps | 1 | 144 | Front squat | |
| Leg press | | | 3-5reps | 1 98 |
| max reps on 75%1RM | 1 | 143 | Leg press | |
| Pull-ups | | | 3-5reps | 1 98 |
| max reps | 1 | 19 | Military press | |
| Strength | 110 | | 1-3reps | 1 102 |
| 1RM | | | Rear elevated split squat (RESS) | |
| Back squat | 10 | 71,95,100,109,145-149 | 3reps | 1 93 |
| Bench press | 13 | 19,71,110,142,145-147,150-155 | Romanian deadlift | |
| Bench row | 1 | 154 | 3-5reps | 1 62 |
| Bent barbell row | 1 | 155 | Weighted chin-ups | |
| Box squat | 3 | 152,156,157 | 3-5reps | 1 62 |
| Chin-ups | 1 | 152 | Adductor Squeeze Test (AST) | |
| Deadlift | 3 | 109,147,152 | Adductor Squeeze Test (AST) | |
| Front squat | 1 | 83 | Spygmomenometer | 3 158-160 |
| Half squat | 1 | 154 | Grip strength | |
| Hex barbell deadlift | 1 | 148 | Handgrip dynamometer | 6 102,114,139,161-163 |
| Leg press | 3 | 110,142,151 | Nordic hamstring strength test | |
| Military press | 1 | 152 | Custom nordic device | 1 164 |
| 3RM | | | | |
| Back squat | 5 | 59,63,72,91,165 | | |
| Bench press | 3 | 89,91,166 | | |
| Chin-ups | 1 | 89 | | |
| Front squat | 1 | 89 | | |
| Prone row | 1 | 89 | | |
| Split squat | 1 | 89 | | |

Table 3.3: Common methodologies for the assessment of endurance in rugby union

| Facet | Reference | Reference | |
|---------------------------------|----------------------------------|--------------------------------------|---------------|
| Test name | | | |
| Mode of testing | | | |
| Surface | | | |
| Aerobic | 42 | Anaerobic | |
| 30min cycle test | | 300m shuttle run | |
| Cycle protocol | 1 167 | Gym floor | 1 168 |
| 3km TT | | 30-15IFT | |
| 3km run | | 30s on-15s off over 40m | |
| Athletics track | 1 169 | Artificial | 1 170 |
| 5RFT | | 40m | |
| run around a track for 5min | | Unspecified | 2 89,171 |
| Outdoor athletics track | 1 172 | Intermittent critical velocity test | |
| Leger shuttle run | | Tread | 1 173 |
| 20m | | modified RSA | |
| Unspecified | 3 111,112,143 | 20m | |
| MAS | | Unspecified | 1 174 |
| 1200m | | 5m cones placed over 25m | |
| Outdoor grass | 1 175 | Indoor hard surface | 1 88 |
| MAS incremental test | | RSA | |
| Outdoor grass | 1 176 | 5x40m | |
| modified MSFT | | Unspecified | 1 146 |
| 20m | | 6x30m | |
| Unspecified | 2 177,178 | Indoor artificial | 1 74 |
| 5m and 10m | | 6x40m | |
| Indoor wooden | 1 87 | Unspecified | 3 130,131,179 |
| MSFT | | 70m total | |
| 20m | | Unspecified | 4 79-81,177 |
| Indoor artificial | 2 19,180 | Cycle protocol | 1 181 |
| Indoor athletics track | 1 182 | YoYo2 | |
| Indoor wooden | 1 87 | 20m | |
| Outdoor grass | 1 183 | Unspecified | 1 184 |
| Unspecified | 5 79-81,98,185 | Rugby-specific | 7 |
| Narbonne test | | BURST | |
| Outdoor grass | 1 176 | Rugby-specific | |
| Shuttle run | | Indoor athletics track | 1 186 |
| 4min repeated efforts (40yards) | | Unspecified | 2 181,187 |
| Outdoor artificial | 1 66 | RHIE test | |
| Vcrit running test | | Rugby-specific | |
| 100, 400, 1500m | | Unspecified | 1 184 |
| Outdoor grass | 1 188 | Rugby-specific circuit | |
| VO ₂ max | | Unspecified | 1 177 |
| Treadmill GXT | | Rugby-Specific Repeated Sprint (RS2) | |
| Tread | 9 74,142,168,173,180,185,188-190 | 20m forwards/30m backs (carrying) | |
| VO ₂ peak | | Unspecified | 2 20,70 |
| Treadmill GXT | | | |
| Tread | 2 71,169 | | |
| YoYo1 | | | |
| 20m | | | |
| Indoor artificial | 2 74,188 | | |
| Outdoor artificial | 1 78 | | |
| Unspecified | 4 89,90,171,185 | | |
| Aerobic/Anaerobic | 1 | | |
| MFITS | | | |
| 1500m/400m | | | |
| Athletics track | 1 104 | | |

3.2.3. Discussion

The purpose of this mini-review was to clarify the trends in the rugby union literature with regard to the tests used to measure speed, strength, and endurance performance. For all of these 3 performance factors there appears to be a multitude of tests used to measure performance. In the literature, there are 9 different distances over which speed is tested. There are 6 different apparatuses used across the various distances, though timing gates were largely in the majority. Additionally, in numerous studies the information about the testing apparatus, the starting position, and the surface was unspecified.

There were 4 different components of strength investigated in the rugby union literature; 1) isokinetic, 2) isometric, 3) muscular endurance, and 4) isotonic strength. The bench press and back squat were most commonly used to test isotonic/general strength.

The MSFT was the most common test of aerobic power, while the RSA was the most common test of anaerobic power. The treadmill VO₂max was a relatively prevalent test within the literature, but it could be questioned as to whether this is an appropriate measure of performance for rugby union.

The literature suggests that these might be the most important tests for rugby union, but the more specific tests should be considered if practical. The trend in the literature should inform decisions, but should not dictate future research and testing. Another noticeable trend is that of an overabundance of different tests attempting to measure the same sub-factor of performance. As suggested by Impellizzeri & Marcora (2009), there should be more rigorous methods used in the process of developing and validating tests and measures.

3.3. PSYCHOLOGICAL

Psychology has not always had a prominent place within sport, but since the onset of professionalism in sport it has been considered an indispensable contributor to performance¹⁹¹. In justifying the importance of the psychological factor Golby & Sheard (2004) recommend establishing psychological attributes and mental skills associated with superior

sport performance to distinguish the potential of players and identify those with characteristics prevalent among elite performers. Indeed, it has been shown that sport psychosocial skills and relevant psychosocial factors can distinguish between rugby union players of different levels of competition¹⁹³. It has been suggested that the psychological factor be broken into “state” and “trait” characteristics of rugby players. That is, “state” refers to characteristics that are relatively changeable, whereas “trait” refers to characteristics which are more stable over time¹⁹⁴.

3.4. STRATEGIC AND TACTICAL

Video-analysis (Notational analysis) has been used in rugby union to describe strategies^{195,196}, and compare the tactics and key performance indicators of winning and losing teams^{197,198}. In the Six Nations tournament, from 2003 up to and including 2006, winning teams (compared to losing teams) tended to kick often, use the maul on attack, and break the defensive line regularly¹⁹⁷. On defence, winning teams effected more turnovers and completed more tackles (94%) than losing teams¹⁹⁷. Similarly, data obtained for the Super 12 competition from 2003 up to and including 2006, revealed that a kicking oriented game combined with a high rate of tackling were most influential in producing a winning outcome¹⁹⁸. Clearly, strategic and tactical astuteness is an important factor in rugby union performance.

3.5. TECHNICAL AND SKILL

At an elite level of rugby union, variations in game statistics cannot be explained merely by physical characteristics²⁰. This leaves room for differences in technique proficiency and skill level of rugby union players to possibly explain dissimilarities in game statistics or performance of players. Technique is generally considered to be the execution of a set of co-ordinated movement actions, while skill involves using technique combined with decision-making, timing, and tactical elements appropriate for the situation^{199,200}. The fundamental element of skill is therefore the cognitive component leading to its use in an appropriate situation²⁰¹. The technical and skill components of rugby union can include passing, catching, kicking, tackling, rucking, mauling, lineout throwing, lifting, and catching, and scrumming^{197,198,202}. Teams can

be more successful when players are more involved in the game by frequently passing, kicking, ball-carrying, tackling, and rucking²⁰³. Gabbett (2002a) found that the physiological attributes of players did not influence selection with regard to semi-professional rugby league players. Selection was in fact influenced mostly by body mass, playing experience, and the skill level of the player²⁰⁴. Similar conclusions were drawn regarding the influence of skill on selection of junior volleyball players for a talent identification program²⁰⁵. Skills that have been measured in rugby league include: 1) tackle technique, 2) draw-and-pass proficiency, and 3) anticipatory skills. These skills exist within rugby union and are relevant to future research²⁰⁶.

3.6. REVIEW SUMMARY

A case has been made for a conceptual model and the 4 factors contributing to rugby union performance. The proposed model breaks down the physical, psychological, tactical, and technical factors into sub-factors relevant to rugby union, and establishes them as measurable components. A better understanding of the tests and measures commonly used for these sub-factors can be achieved by a systematic review of the literature, as was done in part within the physical factor section. As suggested by Hendricks et al. (2015), there is scope for developing quality tests of skill and technique in rugby union. However, based on the previous discussion about clinimetric principles for new measurement tools, it is important for the proposed protocol to be evaluated before it is used for data collection. The next chapter attempts to validate a measure of technical proficiency at the contact situation (tackler and ball-carrier) in rugby union.

4. THE AGREEMENT, RELIABILITY AND ACCURACY OF A SUBJECTIVE-RATING FOR TECHNIQUE MEASUREMENT IN RUGBY UNION AFTER VIDEO-BASED TRAINING

4.1. INTRODUCTION TO THE RUGBY UNION TACKLE

Rugby union is a high-intensity, intermittent sport, characterised by numerous contact events, such as rucks, mauls, scrums, and tackles¹⁻³. On average, a professional rugby union player might incur up to 1.8 match injuries per season⁵. It has been reported that individual forward and backline players can make on average of 11 and 8 tackles per game, respectively². The tackle (tackler and ball-carrier) is also responsible for the highest number of total injuries (69-72%)^{4,5} during a season and can equate to the greatest time away from training and matches⁴. The high rate of tackle-related injuries, 33.9/1000 playing hours at an elite level⁴ and not completely dissimilar from the range of 23.8-34.4/1000 playing hours at u18 level²⁰⁷, is likely associated with the high number of tackle events (48%) that occur during a game⁴. The rate of tackle-related injuries is similar at the junior level, ranging from 29.2-50.0/1000 playing hours for u13's to 23.8-34.4/1000 playing hours in the u18's²⁰⁷. While rugby players have become bigger and stronger since professionalism was introduced in 1995^{15,19}, they have also become more homogenous in their physical characteristics, with little separating players of similar competitive levels⁷⁰. A logical next step to enhancing performance and reducing the risk of playing rugby is understanding and improving the individual skill and technique of players^{35,208,209}. It has been suggested that the most effective tackling and ball-carrying technique is also the safest²⁰⁹. Considering the prevalence of tackles and ball-carries, their propensity to cause injury, and the link between safety and proper technique, a tool for assessing individual tackling and ball-carrying technique would be useful for researchers and practitioners.

Gabbett, Kelly, & Pezet (2007) established a set of criteria, using a 1-to-5 Likert scale for assessing tackle skill in rugby league. The tool was reported as reliable for both intra-rater (ICC=0.85-0.98, TEM=5.1-5.3%) and inter-rater (ICC=0.84-0.94, TEM=7.0-9.0%). Gabbett & Kelly (2007) focussed the criteria towards the assessment of tackle technique in rugby league, and used a dichotomous scale rather than a Likert scale. They reported that the tackle technique assessment tool was reliable (ICC=0.82, TEM=6.7%). This dichotomous scale was used for live assessment during game-related training activities²¹⁰ and video-based assessment of tackling drills^{211,212}. Waldron, Worsfold, Twist, & Lamb (2014) raised concerns over the use of subjective ratings for assessing skill and technique, specifically in the case of Likert scales, reporting low inter-rater agreement between novice and expert raters for passing and catching (30-65%) and tackling (50-65%). However, the intra-rater agreement for the novice rater was deemed acceptable for passing and catching (70-85%), and tackling (80-85%). The raters in that study made their assessments from video footage viewed in real-time. Barring research associated with Gabbett, the dichotomous scale originally used by Gabbett & Kelly (2007) has yet to be verified by an external study.

In contrast to objective measures (e.g. height, weight, distance, etc.), subjective measures (e.g. feelings, energy levels, visual scales, etc.) are more open to interpretation and debate. There are generally two strategies used for addressing problems with subjective rating scales; 1) rating scale development or modification, and 2) rater training²¹⁴. Rating scale modification alone does not seem to address rating scale shortcomings, but there might be a solution in combining the two strategies²¹⁴. However, while there are studies indicating that rater training has an effect²¹⁵⁻²¹⁷, there are also studies suggesting that training was ineffective²¹⁸⁻²²⁰.

Due the relevance of tackling and ball-carrying in rugby union, it's association with injury, and the concerns raised by Waldron et al. (2014) with regards to the use of a subjective measure of skill and technique assessed in a live drill or from real-time video footage, the aims of this study were 1) to determine if undergoing video-based training would improve the agreement, reliability, and accuracy of raters using a subjective-rating measure to assess contact

technique in rugby union, and 2) to establish if a self-selected viewing pace would result in improved agreement, reliability, and criterion-validity over a real-time pace. We hypothesised that 1) the video-based training would improve the agreement, reliability, and criterion-validity of the subjective-rating measurement, 2) a self-selected viewing pace would be superior to assessing tackling and ball-carrying technique at a real-time pace.

4.2. METHODS

4.2.1. Participants

Thirty participants volunteered for this study (table 4.1). Sample size calculations are based on published means and SD's in the field with similar units of measurement, and the estimated required sample size was $12^{212,213,221,222}$. Therefore, it was decided that a sample size of 15 participants per group would be sufficient to detect differences between groups (*a priori* set at 0.05) and allow for potential dropout. Participant information was collected during the initial visit with an electronic form (Google forms, Google Inc., appendix 4.1) on tablet devices. Participants received an information sheet (appendix 4.2) and completed the informed consent (appendix 4.3).

Table 4.1: Descriptive statistics for participants (N=30)

| | All | Non-Training | Training |
|-------------|------------|--------------|------------|
| Age (years) | 25.8 ± 3.1 | 25.3 ± 2.7 | 26.3 ± 3.4 |
| Sex | Female (n) | 11 | 8 |
| | Male (n) | 11 | 7 |

Participants were required to be in possession of a qualification in Sport, Exercise Science, Human Movement Science, Physiology, or equivalent. No prior rugby union knowledge and experience was needed. Participants who have coached a rugby union team(s) formally in the past five years were excluded to reduce any potential influence of learned behaviour from coaching knowledge and experience.

Ethical approval for this study was received from the University of Cape Town, Faculty of Health Sciences, Human Research Ethics Committee (HREC REF: 074/2015, appendix 4.4). Participants were randomly assigned to “training” or “non-training” groups without their knowledge. However, participants were informed about which group they were assigned to after the testing. Participants in the “non-training” group were afforded the opportunity to participate in the training once they had completed their participation in the study.

4.2.2. Study design

This study used a randomised-control design, in which participants were randomly assigned to either a training (experimental) group or a non-training (control) group. The ‘training’ group received training on assessing tackling and ball-carrying technique using a slideshow presentation and video-based instruction and practice. The ‘non-training’ group received pseudo-training on measuring general rugby techniques. Training or pseudo-training was administered during the initial visit (V0). Thereafter, participants returned for 4 more visits to assess the tackling and ball-carrying technique of rugby players. Each visit contained 2 sessions. Within each session, participants viewed 15 randomly ordered clips twice (figure 4.1). Each clip was viewed twice to allow participants to focus on assessing tackling and ball-carrying technique, respectively. The same 15 clips were used for all visits, but randomly ordered for each visit. To reduce the influence of a memory recall effect on participants, visits were separated by at least 6 days to serve as a wash-out period.

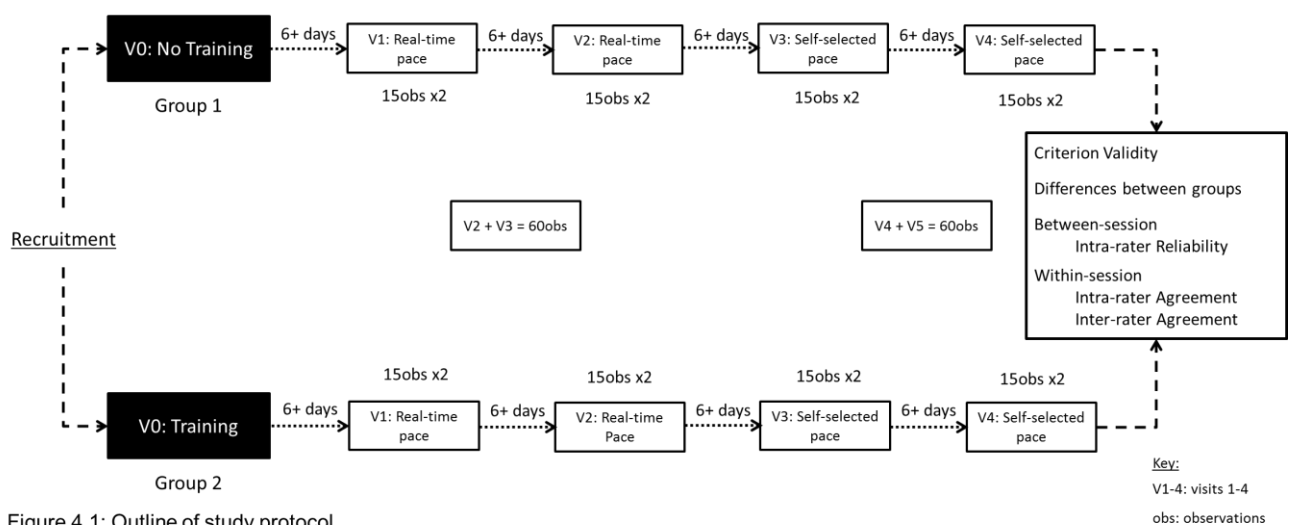


Figure 4. 1: Outline of study protocol

Visits 1 (V1) and 2 (V2) required the participants to assess the clips after viewing it once at a real-time pace. Visits 3 (V3) and 4 (V4) allowed participants to have control over the pace and the number of views of each clip. Participants were asked to decide if the tackling and ball-carrying technique criteria were present by indicating “YES”, “NO”, or “UNSURE” for each criterion on the assessment form. Participants were informed that assigning “YES” to one of the criteria equated to awarding 1 point and that a “NO” equated to 0 points. A score for the

tackler (out of 12) and for the ball-carrier (out of 10) was derived from each clip. The total points for the assessment can be calculated to represent the technical proficiency (arbitrary units or percentage) of the player performing the action in the video clips.

4.2.3. Pilot testing

Pilot testing was conducted to check the testing process. Five participants were recruited and separated into a 'training' group (n=3) and a 'non training' group (n=2). Pilot testing only included the initial visit and two observation sessions, one in real time and one at a self-selected pace. Based on the pilot testing, the participant information sheet was reduced to save time and an electronic form to complete the assessment was chosen (as opposed to physical forms).

4.2.4. Procedures

Training intervention

The initial training and familiarization session was done on a laptop using a slideshow presentation and video-based instruction and practice. The slideshow presentation and video-based instruction and practice was designed to be a 60min self-administered learning tool. With that said, participants were free to ask for help at any stage during the training. Participants were familiarised with the process of assessing tackling and ball-carrying technique by assessing the same 5 clips of tackle situations before and after the 'training' or 'non-training' session. These 5 clips were not included in the main testing sessions.

The 'training' group presentations contained information pertaining to the tackle situation, the tackling and ball-carrying criteria, and the assessment process. Information was presented through text, snapshots from tackling and ball-carrying footage and as video clips of tackling and ball-carrying. The 'training' group did not view the video clips of tackle events from the Six Nations and Rugby Championship.

The 'non-training' group viewed a presentation containing general information pertaining to rugby and viewed real-time video clips of tackle events from Six Nations and Rugby

Championship games. The tackling and ball-carrying criteria were shown to 'non-training' participants but were not explained. No other information on the specifics of the tackle assessment was provided.

Development of the technique assessment tool

Tackling and carrying the ball into contact were assessed using a standardised list of technical criteria (tables 4.2 & 4.3). The standardised technical criteria are based on relevant coaching literature for techniques and published literature in rugby union and rugby league^{35,209,212,223,224}. The initial technical criteria for the ball-carrier and tackler were developed by the researcher(s) based on technique criteria for coaching and previous studies examining tackle contact proficiency. Thereafter, the lists were critically assessed by a rugby research expert group comprising coaches, clinicians, sport scientists, trainers and administrators until a consensus was reached. The tackle situation was divided into 3 consecutive phases; **Pre-contact** (0.4s preceding contact), **Contact**, and **Post-contact** (0.4s following contact)²²⁵. The 'training' group was informed about the timing of the phases, whereas the 'non training' group was not given this information about the timing of the 3 phases of contact. The technique assessment tool was used during the familiarisation part of the training and for the main testing sessions.

Table 4.2: Tackle technique criteria

| Pre-contact | |
|---------------------|---|
| 1 | Identifying the ball carrier |
| 2 | Body position - upright to low body position (dipping movement) |
| 3 | Body position – straight back (spine in line) with torso forward |
| 4 | Alignment – square to the ball-carrier |
| 5 | Arm position – elbows and arms low, close to the body, hands up (boxer stance) |
| 6 | Head position – head up and face forward |
| Contact | |
| 7 | Explosiveness on contact – demonstrates acceleration or/and power step with leading leg on engagement with ball-carrier |
| 8 | Contacting with shoulder against ball-carrier mid-torso |
| 9 | Head placement on the correct side of ball-carrier – Left shoulder=BC left side; Right shoulder=BC right side. |
| Post-Contact | |
| 10 | Arm usage – Punch arms forward, wrap and pull ball-carrier towards himself/herself (hit and stick) |
| 11 | Leg drive upon contact – moderate to rapid knee movement |
| 12 | Shoulder usage - uses shoulder after initial contact to drive upper body into contact |

Table 4.3: Ball carrying technique criteria

| Pre-Contact | |
|---------------------|--|
| 1 | Focus on the point of contact |
| 2 | Shifting the ball away from contact into the correct arm (left or right) |
| 3 | Body position - upright to low body position (dipping movement) |
| 4 | Body position – Straight back (spine in line) with torso forward |
| 5 | Head position – head up and face forward |
| Contact | |
| 6 | Explosiveness on contact – demonstrates acceleration or/and power step with leading leg on engagement with tackler |
| 7 | Body position - From a low body position up into contact (Airplane movement) |
| 8 | Ball protection - Ball in correct arm and protected |
| Post-Contact | |
| 9 | Leg drive upon contact – moderate to rapid knee movement |
| 10 | Arm and Shoulder usage – using the arm and/or shoulder to push tackler |

Technique assessment

After completing the training or non-training visits, all participants conducted tackling and ball-carrying technique assessments in 4 subsequent visits (figure 4.1). Participants viewed video footage of players tackling and carrying the ball into contact during a full contact rugby drill on a laptop computer. The video footage was recorded specifically for the study (discussed in detail later). Participants assessed tackling and ball-carrying technique using the standardised list of technical criteria (table 4.2 and 4.3). All data were collected at the completion of each clip on electronic forms (Google forms, Google Inc., appendix 4.2) using tablet devices. Participants viewed each clip twice per session, the first with focus on the tackler and the second with focus on the ball-carrier. The forms were designed to be simple and easy to complete, however, participants were free to ask assistance at any stage.

Video footage of full-contact rugby drill

To enhance ecological validity and representative design, each of the 15 unique clips contained a match-like tackle event (figure 4.2), performed on a rugby field by six rugby union players from a local club. All players performed a standardized warm-up before taking part in the drill. The borders of the tackle drill were formed by the touchline and the associated 15m line, and the try-line (figure 4.3). The drill was staged to some degree, but it was live and full contact.

The first attacker was instructed to stand in the area approximately five metres back and to the side of the scrumhalf at the ruck. The second attacker was approximately five metres outside the first attacker. The defenders began in a position on the try-line and each marking their opposite attacker. The scrumhalf passed the ball off the ground to the first attacker, at the moment of passing the defenders advanced off the try-line and attempted to tackle their opposition. The instruction to the attackers was to “score the try” over the try line. The instruction to the defenders was to prevent the attackers from scoring through the use of safe and effective tackles. One-on-one tackles occur more frequently in general play than double

tackles²²⁵. For this reason, supporting players were free to move in the drill area, but were instructed to refrain from contacting the contact situation as it occurred, but to provide support on the periphery. The players periodically randomly rotated roles within the drill for the purpose of creating variation in the tackle match-ups.



Figure 4.2: Example of tackle drill footage viewed by participants.

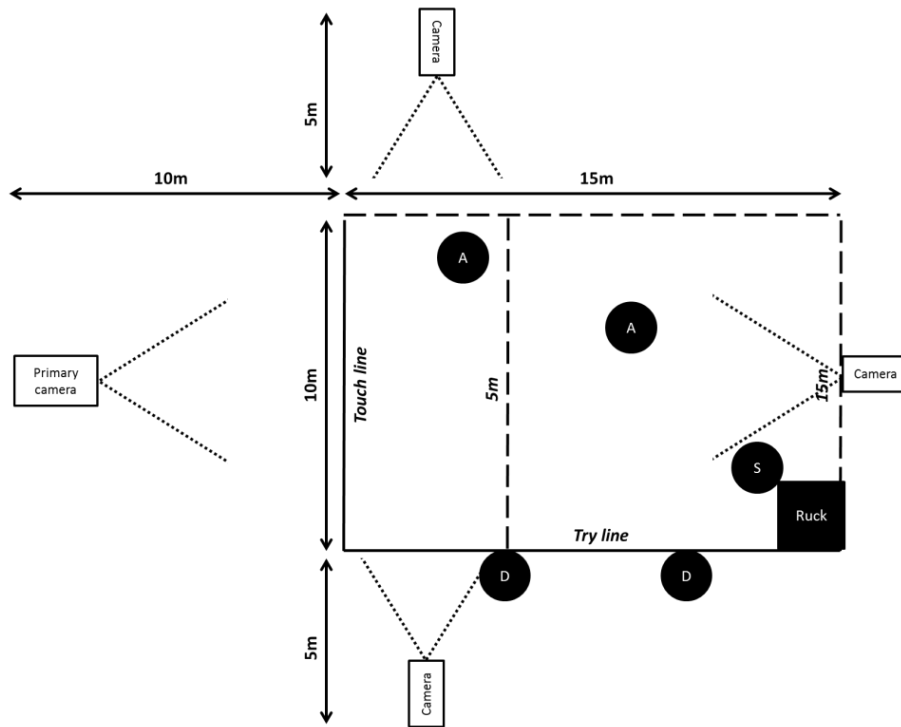


Figure 4.3: Conceptualization of layout for simulated tackling drill to be filmed. *D* = defenders. *A* = attackers. *S* = scrumhalf.

4.2.5. Statistical analysis

Agreement and reliability of the assessments were measured using the proportion of observed agreement (P_o) and Kappa statistics (K) (table 4.4). Agreement was measured i) between the repeated assessments of the same clip by the same rater (intra-rater) within each visit using Cohen's Kappa⁴⁸; and ii) between raters (inter-rater) within each visit using Fleiss Kappa for multiple raters⁴⁹. Reliability was measured iii) between assessments of the same clip (intra-rater) between visits using Cohen's Kappa⁴⁸. Landis & Koch (1977) provide a scale for inferring the magnitude or relative strength of agreement of Kappa (table 4.5).

Table 4.4: Analysis matrix for categorical data

| | Intra-rater | Inter-rater |
|----------|---|--|
| Within- | Agreement P_o , Cohen's Kappa (same rater, clip viewed twice, same session) | Agreement P_o , Fleiss Kappa (multiple raters, clip viewed once, same session) |
| Between- | Reliability P_o , Cohen's Kappa (same rater, clip viewed twice, different sessions) | Reliability <i>Uncertain</i> |

Table 4.5: Landis and Koch categories of relative strength of agreement from the Kappa Coefficient

| <u>Kappa</u> | <u>Strength of Agreement</u> |
|--------------|------------------------------|
| <0.00 | Poor |
| 0.00-0.20 | Slight |
| 0.21-0.40 | Fair |
| 0.41-0.60 | Moderate |
| 0.61-0.80 | Substantial |
| 0.81-1.00 | Almost Perfect |

For the purpose of analysing technical proficiency scoring, the data were treated as continuous. For each of the 15 video clips the tackling technique proficiency was assessed out of 12 and ball-carrying technique was assessed out of 10. The technical proficiency scores from all training and non-training participants were calculated by summing each criterion marked as present for tackling and ball-carrying technique where YES=1, NO=0, and UNSURE=0. Hypothesis testing (paired t-test; $p < 0.05$) was conducted on average technical scores between groups per clip for both real-time and self-selected paces (Stata12, StataCorp LP). Each clip being unique, the scores vary, thus rendering the reporting of an overall mean per group inappropriate. The criterion score for each clip was overlaid on each graph to be a visual indicator of range of scores deviating from the criterion scores.

Accuracy (criterion validity) was measured using the proportion of observed agreement (P_o) by comparing the raters' assessments to a criterion. The criterion validity or accuracy score

then indicates the average percentage or number of correct decisions made by the raters in comparison to the criterion score. To establish a criterion, two of the researchers, with knowledge of the technique assessment and who have used the assessment before, scored the 15 clips at a self-selected pace (agreement of the researchers, $P_o=0.82$, $K=0.62$, Substantial). Between-group differences were compared for training group and viewing pace (paired t-test; $p<0.05$). Analysis of variance (two-way ANOVA; $p<0.05$) was used to determine differences on between-visit average accuracy scores for all visits. For both accuracy and technical proficiency scoring, effect sizes were used to determine magnitude of difference^{33,227,228}. Cohen's effect sizes (ES) were calculated to determine the magnitude of the differences between groups with ESs of <0.19 , $0.2-0.59$, $0.6-1.19$ and >1.2 considered trivial, small, moderate and large, respectively³³.

4.3. RESULTS

4.3.1. Agreement

For assessing tackling technique, inter-rater agreement within the sessions for the training group ranged from 61-63% ($K=0.24-0.26$, Fair) for the real-time pace and 68-73% ($K=0.30-0.38$, Fair) for the self-selected pace. For the non-training group, inter-rater agreement within the sessions ranged from 61-64% ($K=0.26-0.28$, Fair) for the real-time pace and 68-72% ($K=0.29-0.38$, Fair) for the self-selected pace (table 4.6).

For assessing ball-carrying technique, inter-rater agreement within the sessions for the training group ranged from 63-66% ($K=0.15-0.16$, Poor) for the real-time pace and 72-73% ($K=0.12-0.17$) for the self-selected pace. For the non-training group, inter-rater agreement within the sessions ranged from 59-62% ($K=0.15-0.19$, Poor) for the real-time pace and 69-71% ($K=0.17-0.19$, Poor) for the self-selected pace (table 4.6).

Table 4.6: Inter-rater agreement within-session - Observed Agreement (Po) and Kappa coefficient (K ± 95% CI) for assessment of Tackle and Ball Carrying technique

| | | Tackle | | | | Ball Carry | | | |
|---------------|-----|----------------|-----------------------------|----------------|-----------------------------|----------------|-----------------------------|----------------|-----------------------------|
| | | Training | | Non-Training | | Training | | Non-Training | |
| | | P _o | K | P _o | K | P _o | K | P _o | K |
| Visit | 1.1 | 61% | 0.25 (0.21-0.28) | 61% | 0.28 (0.25-0.31) | 63% | 0.16 (0.12-0.21) | 59% | 0.15 (0.11-0.19) |
| | 1.2 | 63% | 0.26 (0.23-0.30) Fair | 61% | 0.26 (0.22-0.29) Fair | 65% | 0.16 (0.11-0.21) Poor | 62% | 0.18 (0.14-0.23) Poor |
| Real-time | 2.1 | 62% | 0.24 (0.21-0.28) | 63% | 0.27 (0.23-0.30) | 65% | 0.15 (0.10-0.20) | 62% | 0.16 (0.12-0.21) |
| | 2.2 | 63% | 0.26 (0.23-0.30) Fair | 64% | 0.27 (0.23-0.30) Fair | 66% | 0.16 (0.11-0.21) Poor | 65% | 0.19 (0.14-0.24) Poor |
| Visit | 3.1 | 68% | 0.30 (0.26-0.33) | 71% | 0.35 (0.31-0.39) | 72% | 0.17 (0.11-0.22) | 69% | 0.17 (0.11-0.22) |
| | 3.2 | 70% | 0.33 (0.29-0.36) Fair | 69% | 0.31 (0.27-0.35) Fair | 73% | 0.14 (0.08-0.20) Poor | 70% | 0.17 (0.11-0.22) Poor |
| Self-selected | 4.1 | 73% | 0.38 (0.34-0.42) | 72% | 0.38 (0.34-0.41) | 72% | 0.16 (0.11-0.22) | 71% | 0.19 (0.14-0.24) |
| | 4.2 | 69% | 0.32 (0.28-0.36) Fair | 68% | 0.29 (0.25-0.33) Fair | 73% | 0.12 (0.06-0.18) Poor | 71% | 0.17 (0.12-0.23) Poor |

For assessing tackling technique, intra-rater agreement within the visits for the training group ranged from 71-76% (K=0.43-0.52, Moderate) for real-time and 82-84% (K=0.61-0.65, Substantial) for self-paced assessments. For the non-training group, tackling technique intra-rater agreement within the visits ranged from 68-77% (K=0.40-0.54, Fair-Moderate) for real-time and 82-83% (K=0.60-0.62, Moderate) for self-paced assessments (table 4.7).

For ball-carrying technique, intra-rater agreement within the visits for the training group ranged from 74-79% (K=0.39-0.48, Fair-Moderate) for real-time and 80-83% (K=0.48, Moderate) for self-paced assessments. For the non-training group, ball-carrying technique_intra-rater agreement within the visits ranged from 67-74% (K=0.31-0.41, Fair-Moderate) for real-time and 78-84% (K=0.47-0.55, Moderate) for self-paced assessments (table 4.7).

Table 4.7: Intra-rater agreement within-session - Observed Agreement (Po) and Kappa coefficient (K ± 95% CI) for assessment of Tackle and Ball Carrying technique

| | Tackle | | | | Ball Carry | | | |
|---------------|----------------|----------------------------|----------------|----------------------------|-------------------|-------------------------|----------------|-------------------------|
| | Training | | Non-Training | | Training | | Non-Training | |
| | P _o | K | P _o | K | P _o | K | P _o | K |
| Visit 1 | 71% | 0.43 | 68% | 0.40 | 74% | 0.39 | 67% | 0.31 |
| Real-time | | (0.41-0.44) Moderate | | (0.38-0.41) Fair | | (0.37-0.41) Fair | | (0.30-0.33) Fair |
| Visit 2 | 76% | 0.52 | 77% | 0.54 | 79% | 0.48 | 74% | 0.41 |
| Real-time | | (0.50-0.54) Moderate | | (0.51-0.56) Moderate | | (0.47-0.51) Moderate | | (0.41-0.43) Moderate |
| Visit 3 | 82% | 0.61 | 82% | 0.60 | 80% | 0.48 | 78% | 0.47 |
| Self-selected | | (0.60-0.65) Substantial | | (0.60-0.62) Moderate | | (0.44-0.50) Moderate | | (0.41-0.49) Moderate |
| Visit 4 | 84% | 0.65 | 83% | 0.62 | 83% | 0.48 | 84% | 0.55 |
| Self-selected | | (0.62-0.66) Substantial | | (0.59-0.63) Substantial | | (0.46-0.48) Moderate | | (0.52-0.56) Moderate |

4.3.2. Reliability

For assessing tackling technique, intra-rater reliability between the sessions for the training group ranged from 74-76% (K=0.50-0.52, Moderate) for real-time and 82-83% (K=0.59-0.62, Moderate-Substantial) for self-paced assessments. For the non-training group, tackling technique intra-rater reliability ranged from 72-75% (K=0.46-0.51, Moderate) for real-time and 79-82% (K=0.53-0.59, Moderate) for self-paced assessments (table 4.8).

For ball-carrying technique, intra-rater reliability between the sessions for the training group ranged from 72-75% (K=0.35-0.38, Fair) for real-time and 82% (K=0.43-0.45, Moderate) for self-paced assessments. For the non-training group, ball-carrying technique intra-rater reliability between the sessions ranged from 69-72% (K=0.33-0.37, Fair) for real-time and 80-81%(K=0.45-0.48, Moderate) for self-paced assessments (table 4.8).

Table 4.8: Intra-rater reliability between-session - Observed Agreement (Po) and Kappa coefficient (K ± 95% CI) for assessment of Tackle and Ball Carrying technique

| | Tackle | | | | Ball Carry | | | |
|---------------|----------------|----------------------------|----------------|-------------------------|-------------------|-------------------------|----------------|-------------------------|
| | Training | | Non-Training | | Training | | Non-Training | |
| | P _o | K | P _o | K | P _o | K | P _o | K |
| Session 1 | 74% | 0.50 | 72% | 0.46 | 72% | 0.35 | 69% | 0.33 |
| Real-time | | (0.49-0.50) Moderate | | (0.45-0.49) Moderate | | (0.31-0.36) Fair | | (0.30-0.34) Fair |
| Session 2 | 76% | 0.52 | 75% | 0.51 | 75% | 0.38 | 72% | 0.37 |
| Real-time | | (0.49-0.55) Moderate | | (0.48-0.54) Moderate | | (0.34-0.40) Fair | | (0.37-0.35) Fair |
| Session1 | 82% | 0.59 | 82% | 0.59 | 82% | 0.45 | 80% | 0.45 |
| Self-selected | | (0.59-0.60) Moderate | | (0.58-0.61) Moderate | | (0.42-0.47) Moderate | | (0.42-0.46) Moderate |
| Session 2 | 83% | 0.62 | 79% | 0.53 | 82% | 0.43 | 81% | 0.48 |
| Self-selected | | (0.60-0.62) Substantial | | (0.51-0.55) Moderate | | (0.42-0.46) Moderate | | (0.44-0.52) Moderate |

4.3.3. Technical proficiency scoring

The differences from the criterion score of the training group tackling technique scores ranged from -1.4 to 3.8 and -0.6 to 2.7 for real-time and self-selected paces, respectively (figure 4.4). The range of the tackling technique score of the non-training group from that of the criterion score was -1.4 to 3.0 for real-time and -0.4 to 2.2 for self-selected paces (figure 4.4). There were significant differences between groups for clip 5, 7, and 13 (ES=0.38, 0.37, and 0.37; Small, Small, and Small) in the real-time pace. In these instances, the non-training group reported lower than the training group for clips 5 and 7, and higher for clip 13.

As a possible confounding factor, the rating of “Unsure” (which equates to 0 points) was minimally represented in the results. For visits 1 and 2 (real-time) the proportion of criteria marked as “Unsure” was 6.1% and 5.1% for tackling. For visits 3 and 4 (self-selected) the proportion of criteria marked as “Unsure” was 0.8% and 1.1% for tackling.

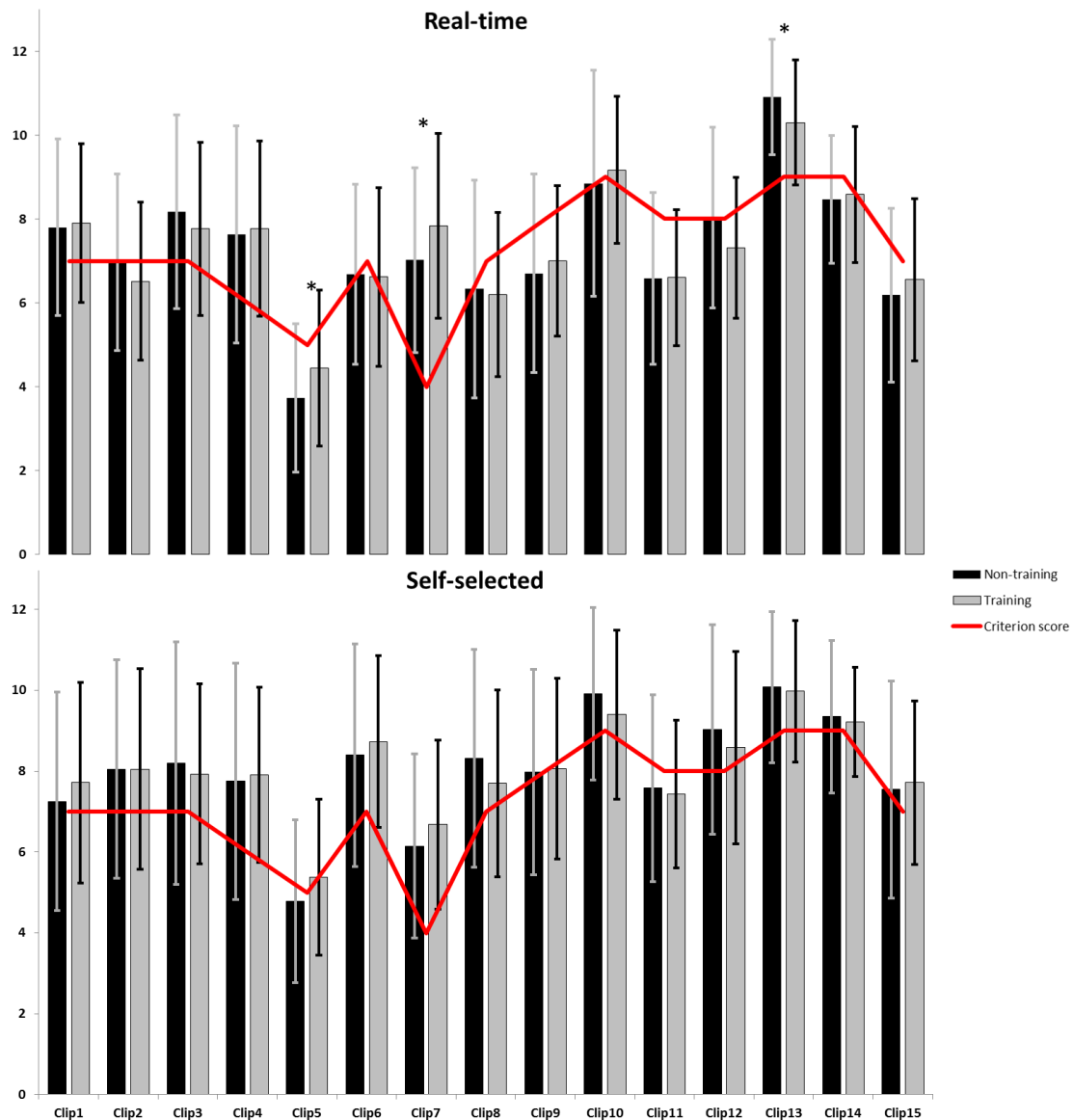


Figure 4.4: The technical proficiency scores of training and non-training groups with criterion scores overlaid for tackle technique assessment.

* training group significantly different to non-training group ($p < 0.05$)

The differences from the criterion score of the training group ball-carrying technique scores ranged from -2.0 to 2.3 and -1.0 to 2.9 for real-time and self-selected paces, respectively (figure 4.5). The range of the ball-carrying score of the non-training group from that of the criterion score was -2.3 to 2.5 for real-time and -1.4 to 2.8 for self-selected paces (figure 4.5). In the real-time pace for ball-carrying technique assessment, clips 7, 12, 13, and 14 were significantly different (ES=0.51, 0.46, 0.50, and 0.41, Small, Small, Small, and Small). In these instances the non-training group reported lower than the training group on all 4 of the significantly different scores for the real-time pace. In the self-selected pace for ball-carrying

technique assessment, clips 7, 12, 13, and 14 were significantly different (ES=0.37, 0.37, 0.54, and 0.37, Small, Small, Medium, and Small). In these instances, the non-training group reported lower than the training group for clip 7 and higher for clips 12, 13, and 14.

As a possible confounding factor, the rating of “Unsure” (which equates to 0 points) was minimally represented in the results. For visits 1 and 2 (real-time) the proportion of criteria marked as “Unsure” was 7.0% and 5.4% for ball-carrying. For visits 3 and 4 (self-selected) the proportion of criteria marked as “Unsure” was 1.6% and 1.6% for ball-carrying.

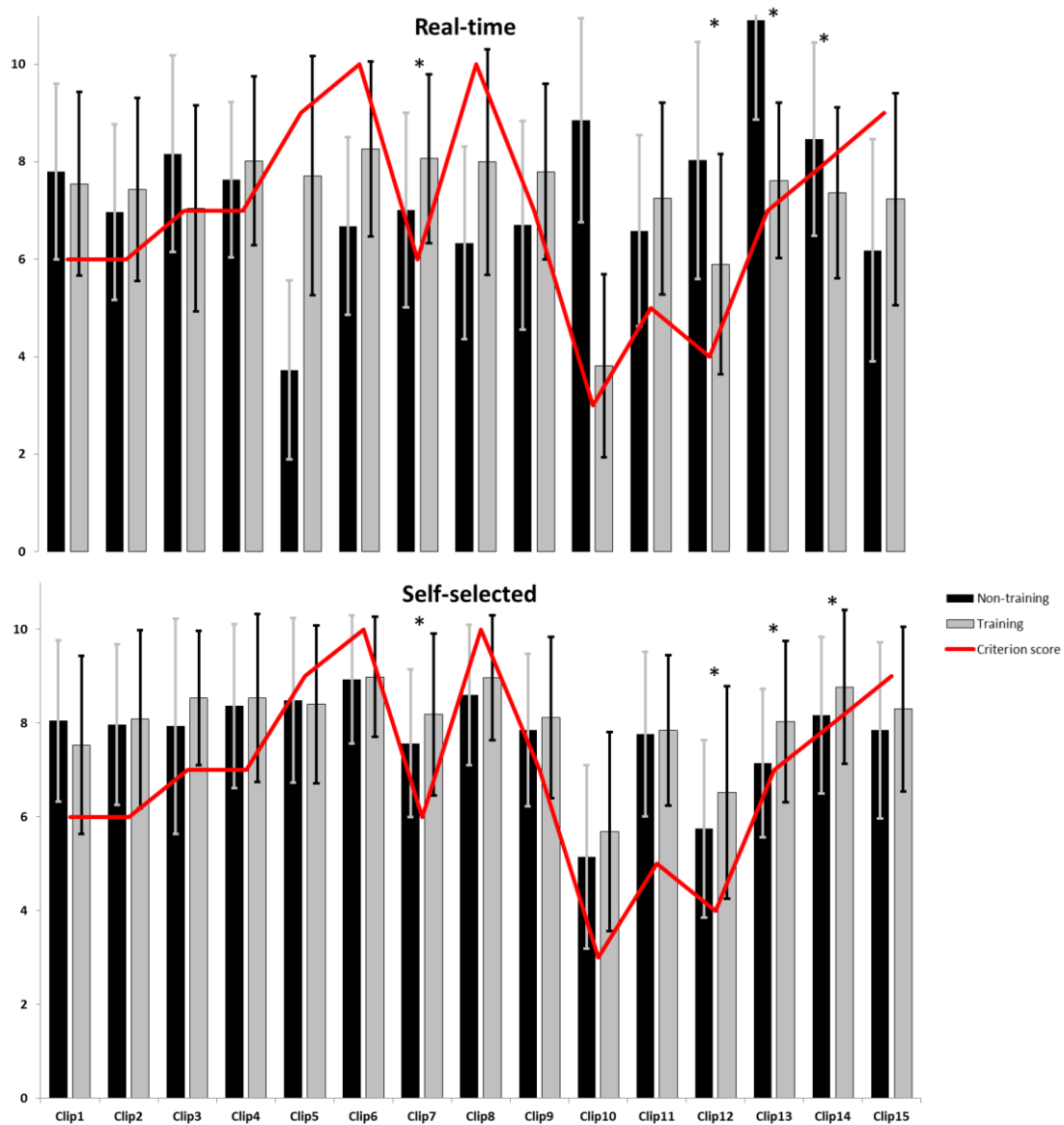


Figure 4.5: The technical proficiency scores of training and non-training groups with criterion scores overlaid for ball-carrying technique assessment.

* training group significantly different to non-training group ($p < 0.05$)

4.3.4. Accuracy (Criterion validity)

Compared to the criterion scores, the training group produced observed agreement of 68% for real-time pace and 74% for self-selected pace for tackling technique (table 4.9). The non-training group produced observed agreement of 66% for real-time pace and 74% for self-selected pace for tackling technique (table 4.9).

Against the criterion scores for ball-carrying technique, the training group produced observed agreement of 67% for real-time pace and 72% for self-selected pace (table 4.9). The non-training group produced observed agreement of 67% for real-time pace and 73% for self-selected pace for ball-carrying technique (table 4.9).

There was a significant difference ($p < 0.05$) between training and non-training groups for the real-time pace ($ES = 0.12$; Trivial). There were no other significant differences between training and non-training groups. When comparing the self-selected pace to the real-time pace in assessing tackling technique, there were significant differences for both the training ($ES = 0.42$; Small) and non-training ($ES = 0.55$; Small) groups. For assessing ball-carrying technique, there were significant differences between self-selected pace and real-time pace for the training ($ES = 0.29$; Small) and non-training ($ES = 0.39$; Small) groups.

Table 4.9: Comparison of criterion validity pertaining to participant accuracy between sessions and between groups

| | | Tackle (/12) | | | |
|---------------|----------|---------------------|--------------------------------|----------------|----------------------------------|
| | | Training | | Non-Training | |
| | | P _o | Score (95%CI) | P _o | Score (95%CI) |
| Real-time | Visit 1 | 68% | 8.2 (8.0 - 8.4) ^{3,4} | 65% | 7.9 (7.7 - 8.1) ^{2,3,4} |
| | Visit 2 | 68% | 8.2 (8.0 - 8.4) ^{3,4} | 68% | 8.2 (8.0 - 8.4) ^{13,4} |
| | Combined | 68% | 8.2 (8.1 - 8.3) [†] | 66% | 8.0 (7.9 - 8.1) |
| Self-selected | Visit 3 | 73% | 8.8 (8.6 - 9.0) ¹² | 74% | 8.9 (8.7 - 9.1) ¹² |
| | Visit 4 | 75% | 9.0 (8.8 - 9.2) ¹² | 74% | 8.9 (8.7 - 9.1) ¹² |
| | Combined | 74% | 8.9 (8.8 - 9.0) [§] | 74% | 8.9 (8.8 - 9.0) [§] |

| | | Ball Carry (/10) | | | |
|---------------|----------|-------------------------|--------------------------------|----------------|----------------------------------|
| | | Training | | Non-Training | |
| | | P _o | Score (95%CI) | P _o | Score (95%CI) |
| Real-time | Visit 1 | 66% | 6.6 (6.4 - 6.8) ^{3,4} | 66% | 6.6 (6.4 - 6.8) ^{2,3,4} |
| | Visit 2 | 68% | 6.8 (6.6 - 7.0) ^{3,4} | 69% | 6.8 (6.6 - 7.0) ^{13,4} |
| | Combined | 67% | 6.7 (6.6 - 6.8) | 67% | 6.7 (6.6 - 6.8) |
| Self-selected | Visit 3 | 73% | 7.3 (7.1 - 7.5) ¹² | 73% | 7.3 (7.1 - 7.5) ¹² |
| | Visit 4 | 72% | 7.2 (7.0 - 7.4) ¹² | 73% | 7.3 (7.1 - 7.5) ¹² |
| | Combined | 72% | 7.2 (7.1 - 7.3) [§] | 73% | 7.3 (7.2 - 7.4) [§] |

1,2,3,4 significantly different to visit 1,2,3,4 (p<0.05)

§ self-selected significantly greater than real-time (p<0.05)

† training significantly greater than non-training (p<0.05)

5. STUDY DISCUSSION

5.1. UNCLEAR SIGNIFICANCE OF TRAINING INTERVENTION

This study set out, in part, to determine the effect of a training intervention on reliability and accuracy of a subjective rating for technique assessment in rugby union. Based on the results, there was no conclusive evidence to suggest that the training group was more reliable or showed higher agreement than the non-training group. Regarding accuracy, the training group was significantly more accurate (ES=0.12, Trivial) when assessing at a real-time pace. However, there was no significant difference when both groups assessed at a self-selected pace. It could be inferred that the training granted an advantage during the real-time viewing pace, but this was nullified during the self-selected viewing visits.

The assessment of ball-carrying technique would appear to be troublesome for raters, regardless of training intervention. Considering both training and non-training groups, the assessment of ball-carrying technique yielded weaker Kappa agreement than that of the tackling technique assessment in most instances. This is most clearly observed in table 4.6, in which all cases of ball-carrying technique assessment achieved weaker Kappa (poor) than that of the tackling technique Kappa (fair). The potential explanations are 1) that the assessment of ball-carrying technique is more difficult than tackling technique, 2) the criteria for assessing ball-carrying technique were not clear to participants and more attention need be given to ball-carrying during the training, 3) or both 1 and 2. It is most likely that the assessment of ball-carrying technique is more difficult than assessing tackling technique, because both training and non-training groups performed worse on this aspect. The implication is that future training interventions should increase the emphasis on ball-carrying technique assessment.

For both tackling and ball-carrying, both groups tended to produce a higher technical proficiency score than the criterion raters (figures 4.4 and 4.5). Additionally, the scoring of all clips by both groups resulted in a notable range of scores. On top of the apparent

ineffectiveness of the training intervention, these deviations from the criterion score could be explained by expert-novice differences in visual gaze behaviour^{229,230}. It has been shown that when compared to novices, expert soccer players fixate their gaze on different contextual cues when performing soccer-specific drills²³⁰. It is possible that the novice participants in this study were attempting to fixate on too many cues and saw tackling and ball-carrying criteria that weren't actually present. On top of this, experts are better at pattern recall than novices²³¹, and the novices used in this study may not have been able to accurately recall whether the criteria were present.

When compared to the criterion scores, all scores for both tackling and ball-carrying technique assessment were above 65% accuracy (table 4.9, 66-75%). It is suggested that the tool appears to be accurate for all groups, however, the training group was significantly more accurate when assessing tackling technique than the non-training group for the real-time pace. There was no significant difference between groups for the self-selected pace, possibly due to a learning effect in the non-training group, or the effectiveness of the self-selected pace for assessment, therefore eliminating the difference between groups from the real-time assessments.

Training interventions for improving the clinimetric properties of tools and measures can have mixed effects²¹⁵⁻²²⁰. A review by Woehr et al. (1994) concerning training interventions for subjective performance appraisals suggested that most training strategies seemed to be at least moderately effective. It is interesting to note the differences in approach to training among the studies, with one study finding no effect on rating accuracy after raters viewed a 15 minute instructional videotape²¹⁹. Similarly, 30 minute or 2 hour training sessions failed to improve the reliability of ratings²¹⁸. Furthermore, a half-day of rater training did not significantly affect the reliability or accuracy of rater scores²²⁰. It would seem then, that more training is needed in future studies, with a minimum of 3 weekly standardised training sessions being the recommendation^{215,216}. On top of the temporal aspect of pedagogical dynamics, the content of the training should be considered. The manifestation of competent practice requires more than

content knowledge and then simply applying that knowledge²³². Participants or learners should be engaged in contextual learning to increase understanding and realise the importance of context when making decisions²³².

5.2. A SELF-SELECTED VIEWING PACE IS SUPERIOR TO REAL-TIME

The second part of this study was to determine which mode of assessment yields the more reliable and accurate results for subjective technique assessments. The self-selected pace appears to be superior to the real-time assessment in terms of reliability and agreement. In all instances of P_o , the results from the self-selected pace were higher than those of the real-time pace. There was a similar trend with regard to the actual Kappa values, though it was not as definitive as with P_o . However, this was not the case with strength of agreement, as seen in table 4.6 in which all instances of tackling and ball-carrying agreement are rated as “fair” and “poor” respectively. Despite the observed increase in P_o from real-time to self-selected paces, the strength of agreement did not increase. This could be expected, as kappa can provide somewhat paradoxical results at times^{43,233,234}. A case could be made from table 4.7 for improved strength of agreement during a self-selected viewing pace. Though, as the Kappa values increase with each visit, this could also be attributed to a learning effect.

In terms of accuracy, the self-selected pace was significantly more accurate than the real-time pace. For both tackling and ball-carrying technique, the training group only showed significant differences in accuracy when real-time visits were compared to self-selected visits. Whereas the non-training group improved in accuracy from visit 1 to visit 3, thereafter the accuracy did not increase significantly. This is possibly explained by a learning effect for the non-training group, who did not receive explicit knowledge of assessing tackling and ball-carrying technique. The plateau for non-training group accuracy seen from visits 3 and 4 possibly indicates that the self-selected pace allowed the participants sufficient time to observe, think, and assess, thus negating any disadvantage from not receiving training. Furthermore, the

proportion of “Unsure” ratings was smaller for both groups for the self-selected pace, indicating more confidence in the raters’ selections. However, the real-time pace could still be considered accurate. Without the aid of definitive thresholds for accuracy, it could be suggested that 66-68% accuracy for the real-time pace is acceptable for novice raters with limited training. This suggestion is not totally unrealistic, as it has been shown in the subjective assessment of cricket-batting skills that a real-time or ‘live’ viewing can yield reliable results equal to the viewing of a recording²³⁵. However, the accuracy of the self-selected pace is still more palatable (72-74%).

5.3. INTRA-RATER ASSESSMENTS YIELD BETTER AGREEMENT

It was not explicitly the aim of this study, but it could be suggested that intra-rater agreement was greater than inter-rater agreement. All instances of inter-rater agreement were “fair” and “poor” for tackling and bally-carrying technique, respectively (table 4.6). Additionally, the P_o ranged from 59-73% over all instances (table4.6). However, the strength of agreement for intra-rater agreement was varied between, “fair”, “moderate”, and “substantial” and the range of P_o was 67-84% (table 4.7). The intra-rater reliability, that is the test-retest reliability of the same rater, could be considered acceptable. The P_o for reliability was above 70% in all but one instance, and strength of agreement was “fair-moderate” and “moderate-substantial” for real-time and self-selected paces, respectively (table 4.8). The inference that intra-rater assessments yield better agreement is in line with the findings of Waldron, et al. (2014), who found that intra-rater agreement for a novice rater was acceptable²¹³.

5.4. HIGHER AGREEMENT DOES NOT ALWAYS EQUATE TO HIGHER KAPPA

The Kappa Coefficient is an index of rater agreement on categorical variables, which represents the extent of agreement that can be achieved beyond chance^{42,43,48}. Additionally, one must consider that on top of chance influencing rater agreement, there is the potential for prevalence of categorical ratings and rater bias to confound the analysis and interpretation of

results. It is due to prevalence and bias that the paradoxical behaviour of Kappa occurs. In terms of prevalence, when a category is more common than others, this creates the first paradox of Kappa, for as the prevalence of a category increases, Kappa will decrease despite P_o ⁴¹. As was the case for inter-rater ball-carrying assessment within the visits (table 4.6), a higher value for P_o does not necessarily translate into a higher value for Kappa^{43,233,234}. The actions or tasks to be performed might not vary sufficiently or might be very common. For example, a participant or athlete might perform certain skill criteria so well that the majority of ratings could be marked as “present”. Looking at the raw data for this study, it was seen that 75% of the responses for ball-carrying technique assessment were “YES”. This clearly indicates category prevalence and can explain the paradoxical behaviour of Kappa seen with the assessment of ball-carrying technique within this study. This phenomenon was less apparent in the assessment of tackling technique with 64% of responses indicating “YES”. The second paradox works otherwise, as bias towards a category increases, Kappa will increase accordingly⁴¹. Raters or coaches might be aware of the “elite” status of an athlete and be biased towards certain ratings. There is also the possibility that raters and coaches could have a personal internal bias towards being more stringent or lenient with their ratings. It is difficult to pinpoint this second paradox in the context of this study, however, the first paradox may hold truth.

5.5. LIMITATIONS OF THE STUDY

The influence of a learning effect on the results of the study should not be dismissed³¹. It is likely that the non-training group reduced their deficiencies in accuracy over the course of the study through assessing the footage over the multiple viewings, implicitly establishing and learning the technical criteria. The non-training group was not explicitly informed about the details of the technical criteria for tackling and ball-carrying assessment, which potentially allowed them to automatically process the information they were receiving during the assessment, and implicitly learn and understand the subjective rating measure²³⁶. A learning effect has also been reported in the subjective assessment of cricket batting skill

assessment²³⁵. In this study, all participants followed the same order of visits, that being the first two sessions as real-time and the remaining two visits as self-selected. It would have been more effective to eliminate the influence of a learning effect by utilizing a randomized cross-over study design, with half the participants from both groups starting with the self-selected pace.

Expert coaches, who are considered to possess knowledge exceeding that of amateurs and novices, can be used to increase content and criterion validity for subjective rating measures. This was the case with Gabbett & Kelly (2007) and Waldron et al. (2014), these being the articles which have most influenced the direction of this study. A third group of expert rugby coaches would have enhanced the comparison and interpretation of the results.

A minor limitation of this study is that there is no predefined acceptable level of agreement. Based on the results of this study and the categories suggested by Landis & Koch (1977), it is suggested that Kappa of 0.41 (Moderate) and above would be an acceptable level of agreement for interpreting the results of categorical data for future agreement and reliability research.

Lastly, training itself is potentially a limitation, as the short, stand-alone period of training (60min) may have been insufficient. While subjective rating measures are not well understood²³⁷, it is possible that if the training intervention had been more grounded in pedagogical practices, there could have been a more significant training effect²¹⁴. Perhaps it would have been more effective to have multiple training sessions or have increased the training period (e.g. 3 weekly sessions). Additionally, the self-learning nature and the content of the training sessions was a possible flaw in the training intervention.

6. CONCLUSIONS

6.1. DID TRAINING IMPROVE RATER METRICS?

The training group was not more reliable and did not show higher agreement than the non-training group. In terms of accuracy, the training group was more accurate when assessing at a real-time pace. However, the self-selected pace condition nullified the advantage of having received training. Ultimately, the training intervention did not improve the rater results, barring accuracy under the real-time pace. Future studies should explore alternative training methods and durations.

6.2. IS THE TOOL USEFUL?

Gabbett would seem to be a keen proponent of the subjective rating measure for skill and technique assessment^{211,212,238,239}. On the other hand, Waldron et al. (2014) are the “would-be” detractors of subjective rating measures of skill and technique. Based on the results and discussion of this current study it could be concluded that in the situation where an individual is able to view footage of tackling and ball-carrying at a self-selected pace, whether trained or untrained, the individual should be able to produce the same results if the footage is assessed within the same viewing period (agreement) or over two separate viewings (reliability). However, it appears that the tool is insufficiently robust when it comes to agreement between different raters. Future research should explore the inter-rater dynamics of assessing tackling and ball-carrying technique.

6.3. PRACTICAL APPLICATIONS

Because it has been suggested that the most effective tackling and ball-carrying techniques are also the safest²⁰⁹, the use of a tool to assess tackling and ball-carrying technique becomes paramount to future research into rugby union and the tackle event. Additionally, the use of a skill assessment should form part of a rugby union testing battery to 1) monitor player development, 2) provide information for players and practitioners, 3) inform planning and

design of training, 4) identify talent, and 5) predict player performance²⁰⁶. This research also suggests that an assessment should be undertaken at a self-selected pace, meaning that video footage of the players tackling and ball-carrying is necessary.

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APPENDICES

Appendix 4.1

Dummy Participant Information form (Click [HERE](#) to view)

Participant Information Sheet

***Required**

Participant Code *

Name *

Surname *

Age (years) *

Gender *

Male

Female

1. Please indicate your highest formal coaching/sport science/physical education qualification(s). *

World Rugby Level 1

World Rugby Level 2

World Rugby Level 3

Formal exercise training course

Undergraduate degree

Postgraduate degree

Other:

2. I confirm that I have not coached rugby formally in the past 5 years. *

YES

NO

3. Are you currently involved in rugby in any capacity? (Other than coaching) *

If your answer is 'NO', please continue to question 4.

YES

NO

3.1 If YES, please indicate your primary involvement.

Administrator

Support staff (Sports scientist, S&C coach, Nutritionist, Psychologist, etc.)

General practitioner

Sports physician

Appendix 4.2

Information sheet



Department of Human Biology

Division of Exercise Science and Sports Medicine
Faculty of Health Sciences, University of Cape Town
Private Bag, Rondebosch 7700, South Africa
Tel: + 27-21-650-4561 Fax: + 27-21-686-7530
Dr Sharief Hendricks
sharief.hendricks01@gmail.com

Measuring Skill in Rugby Union

Information Sheet

Background

Coaches, strength and conditioning coaches, and researchers typically use a standard testing battery as a screening tool to measure physical characteristics of players. The information from this testing battery is subsequently utilized to check whether a player can meet the demands of the sport, talent identification, long-term player development, squad/team selection and/or for designing training programs. Apart from these physical attributes, rugby players also need to efficiently execute a range of technical and tactical skills during a match. Attempts to assess skill in rugby union have been reported, however, little has been documented on assessing skill as part of a team testing battery. Therefore, it is necessary to ascertain the reliability and responsiveness of such an assessment prior to its utilization in practice.

Purpose of this study

The aim of this study is to show the reliability and responsiveness of using a subjective-rating measurement to assess technique in rugby union after undergoing video-based training.

What will be required of you?

It is required that participants be in possession of a 3 year Bachelor's Degree in Sport, Exercise Science, Human Movement Science, Physiology, or equivalent and have not coached a team(s) formally in the past 5 years. No prior rugby knowledge and experience is needed.

Five visits to the Sports Science Institute of South Africa, Newlands, Cape Town to analyze video recordings of players tackling and carrying the ball into contact will be required. Analysis of these video recordings will require you to observe video footage of players tackling and carrying the ball into contact, and then assess the tackle and ball-carrying contact technique using a list of technical criteria. Each visit will consist of 30 observations and last approximately 40 minutes, and separated by 7 days. Visit 1 will be a familiarization/training. During Visit 2 and 3, the video footage will be analysed in real-time. During Visit 4 and 5, you will be able to control the speed of the video footage during the assessment.

What will happen to the data?

Data will be collected using paper and will be stored in a locked cabinet in a locked room with limited access. Thereafter, the data will be captured electronically and stored in databases that are password protected, in a secure facility, and backed-up accordingly. The data will only be used for scientific purposes. The data will be kept for the duration of the study and then placed in storage for a period of at least eight years after publication, at which point the data will be disposed of. Only the principal investigator and participating researchers will have access to the data. Data will be coded with a unique identifier code to de-associate your details from the results.



The University of Cape Town is committed to policies of equal opportunity and affirmative action



Appendix 4.3

Informed consent



Department of Human Biology

Division of Exercise Science and Sports Medicine
Faculty of Health Sciences, University of Cape Town
Private Bag, Rondebosch 7700, South Africa
Tel: + 27-21-650-4561 Fax: + 27-21-686-7530
Dr Sharief Hendricks
sharief.hendricks01@gmail.com

Measuring Skill in Rugby Union

No: Participant Consent Form

I, the undersigned, have been fully informed about the Division of Exercise Science and Sports Medicine within the Department of Human Biology of the University of Cape Town's study to develop a tool for measuring skill in rugby union.

I have also agreed to complete particulars on my level of study, and involvement in coaching rugby. I also understand that all the information that is collected during the study will be treated with the strictest confidentiality and will only be used for scientific research purposes. I also understand that my information will be not released under any circumstances and that all data will be analysed anonymously.

I agree to participate in the study and I have been informed that I will be free to withdraw from the study at any time if I so wish.

I understand the risk of participating in the study is minimal.

I understand that I will receive the overall results of the study. I have read (or where appropriate, have had read to me) and understand the information about this study, and any questions I have asked have been answered to my satisfaction.

Any questions regarding this project may be directed to the Principle Investigator or Student Researcher. This study has obtained ethical approval from the UCT Faculty of Health Sciences Human Research Ethic Committee (FHS HREC). If you have any complaints or queries that the investigator has not been able to answer to your satisfaction, you may contact Prof Marc Blockman of the FHS HREC.

Participant Signature:

Investigator Signature

Date:

| Contact Details: | Phone No | Email |
|---|--------------|-------------------------------|
| Principle Investigator: Sharief Hendricks | 021 650 4569 | sharief.hendricks01@gmail.com |
| Student Researcher: Jason Wulfsohn | 072 228 0107 | jwulfsohn@gmail.com |
| Co-Supervisor: Mike Lambert | 021 650 4558 | mike.lambert@uct.ac.za |
| Research Ethics Committee | 021 406 6492 | mark.blockman@uct.ac.za |
| FHS HREC REF: 074/2015 | | |



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Appendix 4.4

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
Email: sumayah.griefdien@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

26 May 2015

HREC REF: 074/2015

Dr S Hendricks
Human Biology
Sports Science Institute
Newlands

Dear Dr Hendricks

PROJECT TITLE: THE RELIABILITY AND RESPONSIVENESS OF A SUBJECTIVE-RATING FOR TECHNIQUE MEASUREMENT IN RUGBY UNION AFTER VIDEO-BASED TRAINING (MSc candidate-J Wulfsohn) sub-study linked to 211/2014

Thank you for your response letter, addressing the issues raised by the Human Research Ethics Committee (HREC).

It is a pleasure to inform you that the HREC has formally approved the above-mentioned study.

Approval is granted for one year until the 30th May 2016.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the following student:-Jason Wulfsohn is also involved in this project.

Please quote the HREC reference no in all your correspondence.

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

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

Hrec/ref:074/2015

Appendix 4.5

Dummy Tackle and Ball-Carrying Technique Assessment form (Click [HERE](#) to view)

Session 1: Tackle and Ball Carrying Technique Assessment

***Required**

TACKLE TECHNIQUE

After viewing the clip, please use the below form to assess the technique of the TACKLER.

Clip *****

Pre-Contact

1 Identifying the ball-carrier *

YES

NO

UNSURE

2 Body position - upright to low body position (dipping movement) *

YES

NO

UNSURE

3 Body position – straight back (spine in line) with torso forward *

YES

NO

UNSURE

4 Alignment – square to the ball-carrier *

YES

NO

UNSURE

5 Arm position – elbows and arms low, close to the body, hands up (boxer stance) *

YES

NO

UNSURE

6 Head position – head up and face forward *

YES

NO

UNSURE