



# Key Performance Indicators and Predictors in Varsity Cup Rugby

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By:

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## ***Key Performance Indicators and Predictors in Varsity Cup Rugby***

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# Contents Page

Declaration .....	6
Acknowledgements .....	7
List of Figures .....	8
List of Tables .....	11
Abstract .....	12
Literature Review .....	14
Introduction .....	14
Demands of Rugby Union .....	16
Challenges of Tournaments .....	19
Fitness Characteristics .....	20
Anthropometry .....	20
<i>Body Mass</i> .....	20
<i>Stature</i> .....	21
<i>Body Fat Percentage</i> .....	21
Muscular Strength .....	22
Lower Body Explosive Power .....	23
Local Muscular Endurance .....	23
Speed .....	24
Aerobic Endurance .....	25
Coaches' Perceptions and Attitudes .....	26
Video Analysis .....	27
Synopsis .....	30
Aims .....	30
Hypothesis .....	30
	3

Methods.....	31
Experimental Approach .....	31
Session RPE .....	32
Heart Rate Intermittent Monitoring System .....	32
<i>Heart Rate Intermittent Monitoring System Protocol</i> .....	32
Weight.....	32
Anthropometry .....	33
<i>Stature</i> .....	33
<i>Sum of 4 Skinfolds</i> .....	33
<i>Body Fat %</i> .....	34
Muscular Strength.....	34
<i>1RM Bench press</i> .....	34
Sprinting.....	35
<i>10 m and 40 m Sprint Times</i> .....	35
Local Muscular Endurance .....	35
<i>Maximum Pull-ups</i> .....	35
Aerobic Endurance.....	35
<i>Yo-Yo Intermittent Recovery Test</i> .....	35
Coaches' Ratings .....	36
Video Analysis.....	36
Statistics .....	38
Results.....	40
Physical Characteristics .....	40
Heart Rate and Session Load .....	40
<i>Heart Rate Recovery and Session Load</i> .....	40
Changes in Physical Characteristics: Pre-Pre-Season.....	42

Relationships between Physiological Characteristics and the Corresponding Changes over Pre-Season and Pre-Season.....	44
Body Mass Variation .....	47
<i>Average Player Body Mass</i> .....	47
Physiological Variables and Playing Time .....	48
Coaches' Ratings .....	49
<i>Coaches' Average Ratings over the Season</i> .....	49
<i>Coaches' Ratings Regarding Selection and Non-Selection</i> .....	57
<i>Coach 3 (Head Coach) Pre- and Post-Match Ratings</i> .....	61
Video Analysis.....	64
<i>Video Analysis Variables</i> .....	65
Discussion .....	69
<i>Session Load</i> .....	69
<i>Heart Rate Recovery</i> .....	70
<i>Physiological Testing</i> .....	71
<i>Body Mass Variation</i> .....	73
<i>Playing Time and Physical Tests</i> .....	74
<i>Video Analysis</i> .....	76
<i>Limitations</i> .....	77
Summary and Conclusions .....	78
Reference List.....	80
Appendices.....	88
<i>Appendix 1: RPE Scale</i> .....	88
<i>Appendix 2: Coaches' Rating Scale</i> .....	89
<i>Appendix 3: Informed Consent</i> .....	91

## Declaration

I, *Nicola Ann Sewry*, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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## List of Figures

<i>Figure 1: Schematic diagram of the data collection process.</i> .....	31
<i>Figure 2: Diagram of the Yo-Yo Intermittent Recovery Test.</i> .....	36
<i>Figure 3: Average recovery heart rate recovery of the team during the HIMs test each week (sample size varies between n=18 to n=29) and the average session load every practice (sample size varies between n=14 and n=30).</i> .....	41
<i>Figure 4: (a) Average body mass of each player over the course of the season). (b) The coefficient of variation (CV) for each player. (Blank bars represent backline players, striped bars represent forwards)(n=54)</i> .....	47
<i>Figure 5: Correlation between the initial testing battery percentile of a player and the number of minutes played during the tournament (sample size varies between n=26 and n=38).</i> .....	48
<i>Figure 6: (a) Average accuracy ratings of the three coaches for each player over the season. The dotted lines represent the mean and standard deviations (positive and negative). (Unfilled data points represent backs, filled data points represent forwards) (n=50)</i> .....	50

*Figure 7: (b) Average effort ratings of the three coaches for each player over the season. The dotted lines represent the mean and standard deviations (positive and negative). (Unfilled data points represent backs, filled data points represent forwards) (n=50) ..... 51*

*Figure 8: (c) Average focus ratings of the three coaches for each player over the season. The dotted lines represent the mean and standard deviations (positive and negative). (Unfilled data points represent backs, filled data points represent forwards) (n=50) ..... 52*

*Figure 9: (d) Coefficient of variation (CV) for each coach for accuracy. .... 53*

*Figure 10: (e) Coefficient of variation (CV) for each coach for effort. .... 54*

*Figure 11: (f) Coefficient of variation (CV) for each coach for focus. .... 55*

*Figure 12: (f) Average coefficient of variation (CV) for each coach for accuracy, effort and focus. .... 56*

*Figure 13: (a) Median rating of Accuracy of each coach for the selected and non-selected players for the week preceding the match (including quartiles). .... 58*

*Figure 14: (b) Median rating of Effort of each coach for the selected and non-selected players for the week preceding the match (including quartiles). .... 59*

*Figure 15: (c) Median rating of Focus of each coach for the selected and non-selected players for the week preceding the match (including quartiles). ..... 60*

*Figure 16: Coach 3's median player ratings pre- and post-match (including quartiles)(n=33). 62*

*Figure 17: Coach 3's ratings pre- and post-match (n=122). ..... 63*

*Figure 18: (a) and (b) Positive video analysis variables as a total per match (sample size varies from n=8 to n=1028). Mean and the 95% Confidence Intervals are illustrated by gridlines. .... 65*

*Figure 19: (a) and (b) Negative video analysis variables as a total per match (sample size varies from n=3 to n=787).Mean and the 95% Confidence Intervals are illustrated by gridlines. .... 66*

## List of Tables

<i>Table 1: Descriptive characteristics of the forwards and backs at the start of the pre-pre-season.</i>	
<i>Mean ± SD (n).....</i>	<i>40</i>
<i>Table 2: Changes in body mass during the 10 weeks of the pre-pre-season phase. Mean ± SD.</i>	<i>42</i>
<i>Table 3: Changes in physical measures during the 10 weeks of the pre-pre-season phase. Mean ± SD (n).....</i>	<i>43</i>
<i>Table 4: Correlations of physiological characteristics of the players.....</i>	<i>44</i>
<i>Table 5: Correlations between the relative changes in physiological characteristics of the players from pre-pre season to pre-season.....</i>	<i>46</i>
<i>Table 6: All of the performance indicators highlighting the matches for which the number of instances were greater than the upper 95% confidence interval for that performance indicator. .....</i>	<i>68</i>

## **Abstract**

### **Introduction**

Rugby union is a popular sport worldwide, and due to the professional nature of the sport the demands on players continues to increase, resulting in acute and chronic fatigue. The aims of the study were to investigate the tools used to monitor and predict changes in training status and determine the effectiveness of these to: (i) measure the subjective nature of coaches and their selection relating to the players' performance, and (ii) to use performance indicators to correlate to team performance.

### **Methods**

The University of Cape Town Rugby Varsity Cup Team (First XV squad) were monitored from their pre-pre-season until the end of their competitive season. Players completed a testing battery (anthropometry, strength, muscular endurance, speed and aerobic fitness) during the season, along with Rating of Perceived Exertion and body mass was recorded every practice. Players also completed the HIMs test (measure of heart rate recovery) weekly. Coaches rated players every practice on three variables and the matches were recorded and video analysis performed to determine key performance variables.

### **Results**

Most of the players improved in their testing battery between pre-pre-season and pre-season. Average session load varied across the phases of the season and was highest in the pre-pre-season. Change in load however, was not reflected by changes in heart rate recovery which remained relatively stable across the season. The players' body mass varied throughout the tournament, with certain players having a larger coefficient of variation compared to others. There was no relationship between performance in the testing battery and selection for matches. The coaches all had different ratings for the players, with no correlation between players selected

and those not selected. There was a correlation between the subjective rating of players in the week leading up to the match and the match ratings of Coach 3 (head coach).

## **Conclusions**

The Varsity Cup rugby union players followed similar trends described in previous literature in physiological testing batteries, training loads and player management. The novel aspect of this study was the collection of data from the coaches involved. This qualitative data provides insight into the coaches' selection process or lack thereof within a team environment. The data also illustrates the differences between the coaches' interpretation of the players' "performance". The Varsity Cup is a relatively young tournament and should be further investigated to properly understand the differences between it and professional and amateur rugby union.

# Literature Review

## Introduction

Rugby union is an international sport played in over 100 countries worldwide<sup>(1)</sup>, at varying amateur and professional levels. The nature of the sport results in the players having varied physical demands. For example, player position is one determinant accounting for the varying demands on the player during the match. Forwards are generally heavier and taller than backs<sup>(2)</sup>, and although backs run further during a match, the forwards have a higher work to rest ratio than the backs<sup>(2,3,4)</sup>. Also forwards are involved in more contact and collisions with other players compared to backs<sup>(5,6)</sup>. With the sport requiring diverse physical loads on each player<sup>(2)</sup>, and the varying mental and physical fatigue after a match<sup>(7)</sup>, it is difficult for a coach or fitness trainer to manage the training load/recovery relationships which vary for each player. In an attempt to customise the training and recovery some fitness trainers have collected objective and subjective information from players regularly in an attempt to monitor the players to ensure that their training load is adjusted in relation to their symptoms of fatigue<sup>(8,9,10,11,12)</sup>. It follows that making decisions based on evidence, rather than making decisions based on intuition has a better chance of optimising performance of the players in the short term and increasing the longevity of their playing careers in the long term<sup>(13)</sup>.

Rugby players at all levels perform large amounts of both gym-based and on-field training to improve performance. This occurs during both the pre-season and in-season<sup>(14)</sup>. If this training is not managed properly it can lead to over-reaching and a concomitant decrease in performance<sup>(15)</sup>. The definition of over-reaching is: “accumulation of training and/ non-training stress resulting in short-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of maladaptation in which restoration of performance capacity may take several days to several weeks”, however the definition of overtraining is: “and accumulation of training and/ stress resulting in long-term decrement in performance capacity with or without related physiological and psychological signs and symptoms of maladaptation in which restoration of performance capacity may take several weeks to several months”<sup>(16)</sup>. It is unknown at what point the players start showing detectable symptoms of overtraining, but new measures are being developed to help monitor this in an attempt to prevent players from

becoming overtrained. Some studies have used biochemical markers<sup>(17,18,16)</sup> to illustrate the effect of training as well as recovery on these specific biochemical markers (both in terms of muscle damage and various hormonal changes in response to stress). However these methods are sometimes invasive, lack sensitivity, are costly and impractical for team sports, such as rugby union, which have long competition periods.

The Varsity Cup tournament is a relatively new tournament having only begun in 2008. The aim of the tournament is to promote young talent (players must be below the age of 25 years) within the university environment. The structure of the tournament poses many challenges. One challenge lies with players sometimes entering the tournament straight out of school. This sudden increase in training load and size of both the opposition and teammates raises concern about the physical preparedness of some players. For the coaches, the high turnover of players (as players turn professional, get injured or leave university) does not allow for much time for coaches to get to know players well. These factors all contribute to a tournament with unique challenges.

In response to these challenges, practical measures need to be implemented to avoid overtraining/overreaching without being invasive or excessively time consuming. An example of a non-invasive measure is the Rating of Perceived Exertion Scale (RPE)<sup>(19)</sup> This method was successfully implemented in rugby league training by Lovell *et al.*<sup>(20)</sup>. RPE is used as a measure of the internal load a player is experiencing. Session RPE can evaluate how hard the player perceived the session to be with a rating from the player<sup>(20)</sup>. RPE is a subjective measure which can be influenced by extraneous factors<sup>(19)</sup> and therefore should also be supported by objective measurements. Heart rate recovery after exercise, is an example of an objective measure, that has been shown to be an indicator of the changes occurring in the autonomic nervous system (governed by the changes in the parasympathetic and sympathetic nervous systems<sup>(21,22)</sup>). Both measures (Session RPE and recovery heart rate) are non-invasive, cost effective and time-efficient and both have been shown to be accurate markers of training status and fatigue<sup>(8)</sup>

However, whilst monitoring rugby players regarding their response to training is important, as discussed above, measuring the baseline fitness and strength of the players is also important from a best practice perspective<sup>(23,24)</sup>. These testing batteries, specific for the demands of rugby union,

are commonly implemented for talent identification programs <sup>(23)</sup>. The results from the tests also assist coaches in making decisions about selection. The concept of selection, and the methods associated with selection, by coaches within rugby union are not well understood. The combination of markers of fitness <sup>(25)</sup>, technical proficiency<sup>(23)</sup>, experience<sup>(26)</sup> and attitudes (both coaches and players)<sup>(27)</sup> provide the coaches with a holistic view and the capability to select players. However, the extent that each of these is used to influence decisions about selection has not previously been quantified.

These various monitoring tools and testing batteries can assist the coaches in selection and understanding the players and their needs and responses to the training/stresses imposed on them. However, these tools can only be useful if they are understood in more detail. The next section will discuss these factors in more detail, and develop the questions which will be answered in this study.

## **Demands of Rugby Union**

Understanding the intricacies of the sport is integral to knowing the task requirements for an action outcome. The “game sport” of rugby union consists of two teams competing against each other, with each team made up of 15 players<sup>(28)</sup>. The matches for senior players are 80 minutes in duration, with the ball however, only in play for an average 30 minutes of the 80 minutes due to stoppages for injuries, penalties and various other reasons<sup>(28)</sup>. Each of the 15 players on the field has a specific position (outlined by the International Rugby Board rules and guidelines)<sup>(29)</sup>. These 15 positions are: 1) loose head prop; 2) hooker; 3) tight head prop; 4) left lock; 5) right lock; 6) left flanker; 7) right flanker; 8) number eight; 9) scrum half; 10) fly half; 11) left wing; 12) left centre; 13) right centre; 14) right wing; 15) full back<sup>(29)</sup>. More commonly the positions are referred to as the forwards (positions 1-8) and the backs (positions 9-15).

It has been well documented that the physical demands on each player are different depending the playing position. As a consequence players with certain physical characteristics are suited for specific positions<sup>(2)</sup>. Lee *et al.* researched the physique of rugby union players in Scotland during the 1993-1994 season and showed that there was a significant difference between forwards and

backs in mean BMI (body mass index) (backs had a lower BMI than the forwards), PI (ponderal index) (backs were higher than forwards), height (variable) and weight (backs weighed less than forwards)<sup>(30)</sup>. The forwards are responsible for contesting the possession of the ball (especially at the breakdown, thus they need to be heavier to give them a physical advantage), whereas the backs are usually faster than the forwards and are used for advancing territory and scoring points<sup>(31)</sup>. Regardless of the position of the player, rugby requires the players to have well developed endurance, speed, agility, power, flexibility and sport-specific skill<sup>(2)</sup>.

The physical characteristics of the players, measured with a battery of tests, are related to the players' match performance. For example, the physical characteristic of maintaining prolonged high-intensity running (within a laboratory test) allowed for players to perform larger amounts of high-speed running, as well as greater distances overall within rugby league matches<sup>(32,33)</sup>. Also a better performance of players in the 10 m sprinting test and counter-movement-jump tests was associated with an increase in successful ball-carries within matches<sup>(34)</sup>. Another study analysing video recordings during a game, showed an association between speed and activities involving high-intensity running (such as tries), whilst upper body strength correlated with turnovers (this will be further discussed in the Fitness Characteristics section)<sup>(35)</sup>. The need for faster recovery is also pertinent in rugby. A study showed that players with better performance in the Yo-Yo test (IR1) and 3 repetition maximum (3RM) squat, recovered faster after a match compared to those players who did not perform as well in the test<sup>(33)</sup>. This translation of physical characteristics into match performance and post-match fatigue provides the link between the laboratory tests and match situations.

It is also important to understand the physical nature of rugby union when attempting to identify monitoring tools. Rugby union has a high incidence of injury (an incidence of 57.2 per 100 playing hours<sup>(36)</sup> compared to 8.0 per 1000 in English football<sup>(37)</sup>), with tackles accounting for approximately 58% of all injuries<sup>(31)</sup>. During the tackle situation, the collision causes muscle damage (illustrated by an increase in blood creatine kinase)<sup>(38)</sup>. While the muscle damage is not always the direct cause of injuries, it can lead to players feeling fatigued and not performing at their peak. This association between the tackle situation and muscle damage is important considering that each forward is subjected to on average 18-25 tackles per match, whilst the backline players are subjected to 15-18 tackles per match<sup>(39)</sup>. The repeated bouts of muscle

damage/recovery can cause chronic fatigue, particularly as the season progresses. This is one of the factors contributing to the need for player monitoring to ensure that they maintain peak fitness.

## Challenges of Tournaments

Tournaments are unique in their format, in that the players are exposed to a high number of matches in a short period of time, with little time for recovery. Studies have shown the injury rates are high across all levels with for example, 69 injuries per 1000 playing hours in elite rugby (normal matches)<sup>(40)</sup>, 78 injuries per 1000 playing hours in the 2001 Under-21 championship (tournament)<sup>(41)</sup>, and 98 injuries per 1000 playing hours during the 2003 Rugby World Cup (tournament)<sup>(42)</sup>. There was an injury incidence of 57 injuries per 1000 match playing hours at the IRB (International Rugby Board) Under-20 junior world championship<sup>(36)</sup>. Tournaments vary in duration, for example the South African youth week tournaments are a maximum of only 6 playing days<sup>(43)</sup>, whereas a tournament such as Super Rugby extends a period of approximately five months and a total of 1364 hours of playing time<sup>(44)</sup>. However, whilst these tournaments vary in duration, the injury incidence is still large contrast to that of the normal match schedules. Although injuries are important when analysing a rugby union tournament, illness also becomes prominent in such long tournaments. In the 2010 Super 14 Rugby tournament, the tournament of 16 weeks long saw an incidence of illness of 21 illnesses per 1000 player days (the cohort comprised of 22676 player days), illustrating the toll the tournament takes on the players<sup>(45)</sup>. Some of the elite compete in multiple tournaments (e.g. Super Rugby, Tri-Nations and end of season tours) per year<sup>(44)</sup>.

Preparation for a tournament is also difficult, as the demands of the tournament have to be factored in along with the demands of the entire season, before and after the tournament. Also players in high level tournaments have additional stress such as increased demands from the supporters and media<sup>(42)</sup>. Research shows that during tournaments there is an increased need for the physical and mental management of players<sup>(42)</sup>.

The Varsity Cup tournament is a relatively new tournament implemented by the South African Rugby Union in 2008<sup>(46)</sup>. The aim of implementing such a tournament was to help South African universities rejuvenate the sport as well as provide a platform for players to display their skills<sup>(46)</sup>. The tournament comprises eight university teams who play each other once on a yearly alternating home and away basis<sup>(46)</sup>. The tournament starts in February and the play-offs occur

eight weeks later. Although the tournament is only in its seventh year, it is already the third largest domestic rugby tournament in South Africa<sup>(46)</sup>. Considering this information, the tournament is unique and cannot be assumed to have the same challenges as other tournaments. The tournament has now also become a feeder for professional teams and therefore, more in depth research into the challenges of this unique tournament are needed.

## **Fitness Characteristics**

### **Anthropometry**

The physical attributes of rugby union players differ according to both their playing position and level of play. Forwards and backline players (backs) fulfil different roles within the team, which require different physical attributes.

#### *Body Mass*

Forwards are generally heavier than the backs at all levels of rugby<sup>(2)</sup>. The larger body mass of forwards is largely due to the need for increased scrummaging force and ability to compete at the breakdown, whereas the backline players need to be more agile, faster and mobile and therefore have a lower overall body mass than the forwards<sup>(47,48)</sup>. The average body mass of all players increases as the level of rugby increases<sup>(2,35,49,50)</sup>. For example, the size of players has been linked to performance at the Rugby World Cup<sup>(26)</sup>. The teams that performed better (won, reached finals, or any play-offs) had a larger cumulative weight of forwards, and the similar trend was found within the backline players<sup>(26)</sup>. Body mass within a more homogenous sample, however showed no significant association between starters, non-starters and non-selected players in a study using rugby league players<sup>(23)</sup>, illustrating that within a squad body mass could not be determined as a factor directly leading to selection in the team. However, another study in rugby league showed a significant association between body mass and the number of minutes played for the team (lower body mass associated with more minutes played)<sup>(51)</sup>. The level of play has shown senior A forwards to be 11% heavier than senior B forwards<sup>(52)</sup>. However, within a

professional team (a homogenous sample), an 18% difference between forwards and backs can be seen<sup>(49)</sup>, illustrating the large variance between both positional groups and level of play for body mass.

Over time, the body mass of players has also increased. When looking at rugby union players between 1905 and 1999, the secular trend has shown an increase in body mass, height and BMI (body mass index)<sup>(48)</sup>. The body mass and BMI of rugby players in particular (within this study), has increased at a rate of over twice the average rate over the century, illustrating the changes in rugby players<sup>(48)</sup>. A study of senior and junior French rugby players showed that the players have become heavier (seniors: forwards by 12.3 kg, backs by 12 kg, juniors: forwards increased by 11.1 kg, backs by 9.9 kg), indicating the need for heavier players in the modern game<sup>(53)</sup>.

### *Stature*

The forwards are generally about 4% taller than the backs<sup>(54)</sup>. The demands of the lineout, with the need to be able to jump higher than the opposition to secure the ball, plays a large role in the need for the forwards to be taller than the backs, especially in the lock position<sup>(2)</sup>. Hookers and inside backs on the other hand, are generally the shortest players in the team<sup>(2)</sup>. The players are generally taller as the level of play increases. For example, 1<sup>st</sup> class players were taller than 2<sup>nd</sup> class (forwards were taller by 3%)<sup>(2)</sup>. In another study, the differences between senior A, senior B, under-21 and under19/18 showed a similar trend (for forwards a 3% difference between senior A and B, and 2% between under-21 and under-19)<sup>(49)</sup>. When looking within a team however, the stature of a player was not shown to be significantly different between starters, non-starters and non-selected players<sup>(23)</sup>.

### *Body Fat Percentage*

Body fat percentage is measured as part of a testing battery for rugby union players as a proxy of their physical condition. A common method is to measure the sum of skinfolds method and then use the Durnin and Womersley<sup>(55)</sup> equation to predict body density equation, and the Siri equation to predict the player's body fat percentage<sup>(55)</sup>. Forwards generally have a higher body fat percentage compared to backs, and the higher the level (1<sup>st</sup> class, 2<sup>nd</sup> class and university

levels) the lower the body fat percentage of the players<sup>(2)</sup>. At any given body mass, a lower body fat percentage, is associated with an increased ratio of lean body tissue versus fat, resulting in an increased power-to-weight ratio, increasing the acceleration capacity of the player and a decreasing energy expenditure when compared to a player with a high body fat percentage<sup>(56)</sup>. Given the differences in demands (e.g. running for the backs and contact for the forwards), it is not surprising that the backs usually have a lower body fat percentage when compared to the forwards. Sum of skinfolds or body fat percentage, was also found to be different between the players within a squad who were never selected and those who were “starters”, as well as, the “non-starters” (the study was compiled over a four year period) illustrating the impact of body fat percentage of a player and their selection for a match<sup>(23)</sup>. Similarly, Gabbett *et al.* showed that the higher the sum of skinfolds of a player, the fewer minutes they played over the season<sup>(51)</sup>.

## **Muscular Strength**

There are a high number of contact situations during a game in rugby union, therefore strength and the ability to produce a force is an important physical characteristic<sup>(35)</sup>. Video analysis has quantified the demands on the players according to their positional groups<sup>(57)</sup>. This has shown that the percentage of time spent performing tasks where upper body strength is a primary contributor (such as tackling, competing for the ball and scrummaging) for forwards was between 2-7% more when compared to that of the backline<sup>(57)</sup>. The forwards generally have a larger absolute bench press capability when compared to backs<sup>(58)</sup>. It must be kept in mind that due to these differences between forwards and backs the training programs prescribed to the players will vary<sup>(57)</sup>. In particular, props have a larger upper body strength compared to scrumhalves and fullbacks, illustrating that the front row players (e.g. for the scrum) have increased strength<sup>(58)</sup>. The absolute versus relative bench press weight is important to consider, because backline players usually have a lower body mass compared to that of the forward players<sup>(2)</sup>. Upper body strength is often used during the tackle situation to perform tasks such as the hand off. Performance in the bench press was positively associated with the number of turnovers performed by a backline player in a match situation<sup>(35)</sup>.

## **Lower Body Explosive Power**

Lower body explosive power in rugby union players is an important physical attribute, as it contributes to many of the skills involved with the sport. For example, explosive power is associated with sprinting, striding, changes in direction and tackling (where a leg drive is beneficial)<sup>(59)</sup>. The vertical jump height is a measure commonly used to quantify a player's lower body explosive power<sup>(2)</sup>. Backline players generally have a higher vertical jump height, when compared to forwards<sup>(2)</sup>. The same review also found a trend that the jump height of both forwards and backs decreased slightly as the level of rugby increased. However, this conclusion was derived from years of data (between 1969-2000), where the method for calculating the vertical jump height has changed<sup>(2)</sup>. However, in more contemporary research, Gabbett has shown vertical jump height increases as the age group and level of rugby increases<sup>(60)</sup>. An increased vertical jump height has also been associated with an increased defensive performance (including tackle attempts, tackles completed, dominant tackles, tackle efficiency) illustrating the need for lower body explosive power with game situations<sup>(51)</sup>. Research also shows a significant difference between players selected to play in the match (starters and non-starters) when compared to the non-selected players over a couple of seasons<sup>(23)</sup> of senior players. In junior players however, there was no significant difference in jump height between starters and non-starters<sup>(25)</sup>. Following on from this, the lower body explosive power of a player increases during the competitive season, however, with this increase, a decrease has been shown to occur towards the end of the season (due to the increased match load)<sup>(61)</sup>.

## **Local Muscular Endurance**

Whilst the ability to produce a maximal force in rugby union is imperative to complete the tasks required during the game<sup>(35)</sup>, the ability to maintain the same levels of force as the game progresses is another physical attribute which is important for the players. With tackling playing a large role in rugby union, the ability to maintain tackling proficiency becomes imperative<sup>(62)</sup>. Especially within tackling, local muscular fatigue has been shown to occur during matches and have a negative effect of skill<sup>(62)</sup>. Upper body muscular endurance is often represented by the number of pull ups or chin ups a player is able to do<sup>(35,63)</sup>. Forwards generally perform fewer pull

ups compared to backline players<sup>(64)</sup>. This could be a consequence of the backs having a lower body mass and therefore having less of a load to lift and lower, compared to the forwards. From a performance perspective, Smart *et al.* showed that there was a significant correlation between the number of pull ups performed in the testing battery and the number of turnovers performed by the players within a match<sup>(35)</sup>. This correlation was true for both backline and forward players, showing the importance of upper body muscular endurance within a match context<sup>(35)</sup>.

## Speed

With rugby being an intermittent high intensity sport, both speed and endurance are important physical attributes. In rugby union the average distance per sprint a backline player sprints during the match is 13.6 m whilst a forward on average will only sprint 12.3 m<sup>(65)</sup>. On average, over an hour of play, the backs will sprint 346 m and the forwards 220 m, thus indicating the need for backs to be more proficient in their sprint times<sup>(65)</sup>.

Most test batteries will include sprint times over distances of 40 m and less<sup>(65)</sup>. Quarrie *et al.* illustrated a significant difference, both senior club and school level players, between forwards and backs in their 30 m sprint times (for both a standing and running start), with the backs being faster than the forwards<sup>(49)</sup>, whilst Gabbett showed the same difference but in the 40 m sprint within amateur and semi-professional senior players<sup>(50,66)</sup>. Studies have also shown an increase in speed as the level of rugby increased (including the change from age-group rugby to seniors)<sup>(49,25,60,66)</sup>. The sprint times are not only different between positional groups, but also between the players selected and those not. The sprint time for both 10 m and 40 m sprints were faster in starters compared to both non-starters and the non-selected players, illustrating the importance of sprint speed in selection<sup>(23)</sup>. However, in juniors below the age of 17 years, the speed (10 m, 20 m and 40 m) was not different between the starters and non-starters<sup>(25)</sup>. An association between faster sprint times and an increase in the number of tries scored has been shown, whilst defensively, faster speed times are associated with an increase in tackle attempts and tackles completed<sup>(51)</sup>. Correlations between sprint speed and line breaks, tackle breaks, metres advanced and evasive manoeuvres all support the need for the selection of faster players<sup>(35)</sup>.

## **Aerobic Endurance**

Many physical tests have been developed to test the aerobic fitness of rugby union players. One of the more widely used tests is that of the Yo-Yo Intermittent Recovery test<sup>(67)</sup>. The higher the level or distance covered during the Yo-Yo test is used as the measure of aerobic capacity in sports testing. This test is predominantly used for the evaluation of physical performance for players participating in the intermittent sports (such as rugby union). As the duration of the Yo-Yo test increases, the players' heart rate gradually increases due to the increasing workload<sup>(67)</sup>. At the end of the test the heart rate is within 1% of the athlete's peak heart rate when completing a  $VO_{2max}$  test on the treadmill<sup>(68)</sup>, which suggests that the test is a valid and reliable measure of a player's aerobic capacity. The test is not the best measure of a  $VO_{2max}$ , but is a very good measure of a player's ability to repeat efforts. As with most aerobic endurance tests, pre-season aerobic training has proved to increase the results of the Yo-Yo test, illustrating its sensitivity to changes in physiological fitness<sup>(67)</sup>.

A significant difference between elite and moderate-elite soccer players' Yo-Yo test results has been shown, indicating the correlation between fitness levels of players in higher and lower leagues<sup>(68)</sup>. The differences in fitness levels between leagues could be due to the influence of the Yo-Yo test results on selection of players within these leagues.

Previous research into the relationship between the Yo-Yo test results and a player's performance within a match, has been limited to the analysis of the duration of high-intensity exercise performed during the match by professional soccer players<sup>(69)</sup>, thus providing a good indicator of fatigue during the match. However, due to the nature of intermittent team sports, limited research exists on the relationship between the Yo-Yo test results and technical performance within the match environment.

## Coaches' Perceptions and Attitudes

It is widely accepted that factors such as the players' anthropometrical and physiological characteristics influence the coaches and contribute significantly to the selection of players in rugby union <sup>(2,66,70,25,71)</sup>. However, there are other factors that affect the final decisions made by the coaches. These will be discussed below.

The role that coaches perform is based on their experience, knowledge, values, opinions and beliefs<sup>(27)</sup>. Based on that model, each coach will perceive situations and players in a different way. Some coaches would have played the sport earlier in their life; these experiences will help shape their view of the players and the way they perceive their performance. In basketball, a set criteria (with defined variables) was determined to help guide coaches with selection<sup>(72)</sup>. However this guide only considered their previous match performance in making decisions about selection, making their performance at practice almost irrelevant<sup>(72)</sup>. This approach seems flawed because the way the players both act and perform at practices, in particular their focus, effort and accuracy in executing a required task or drill should be pivotal to their selection the following week. However, despite this being logical in influencing how coaches select players for a match, there does not seem to be a formal study on these aspects of selection.

As discussed previously, monitoring the training load/recovery is important for the long term management of the players. In many cases it is the coaches who are responsible for interpreting the outcomes of the monitoring and imposing the training. When teams underperform, it is often assumed by coaches that this is due to an inadequate amount of training. With this said, the underperformance has been proven to be partly due to the lack of correspondence between the coach and the player regarding the execution of the designed programme<sup>(73)</sup>. This conclusion was derived from the study which used the session RPE scale multiplied by the session duration to quantify the training load. The results showed there was a significant difference between the intended "hardness" of the session according to the coach's rating compared to the "hardness" as experienced by the players<sup>(73)</sup>. The days the coaches intended to be low intensity or a rest day, the players perceived to be harder, whilst the sessions intended to be high intensity, the players undertrained<sup>(73)</sup>. This gap in communication can easily be linked to overtraining or under-

training, both having unintended consequences. The communication between coaches and players alike has to be well synchronised for the desired results to be achieved.

## **Video Analysis**

As professionalism in rugby union continues to grow, technology is being used more to evaluate team and individual performance during training and matches. Video analysis of practices and matches is an example of technology being used to determine predictors for outcomes such as successful tackles, injury prevalence and the workload of rugby union players<sup>(3,74,75,76)</sup>. The application of evaluating performance using video analysis is present in the use of the Eagle Rating (the rating system for fantasy rugby union during the Super rugby tournaments<sup>(77)</sup>). This system identified specific variables in a certain match that were associated with the player's performance<sup>(77,78)</sup>. These data were designed for the SuperRugby tournament (professional) and perhaps not as relevant for lower levels of rugby. These variables were also based upon specific playing positional groups and therefore tailored to the individual and not on a team level.

Vaz *et al.*<sup>(79)</sup> looked at similar variables for international and Super twelve matches (only close matches were included in the analysis, defined as the score between the winning and losing team was 0-11 points) and determined that there were variables which could discriminate between a team winning and losing a match. The variables used were<sup>(79)</sup>:

- rucks (winners fewer)
- pass (winners fewer)
- mauls won (winners fewer)
- turnovers won (winners fewer)
- passes completed (winners fewer)
- possession kicked (winners greater number)
- kicks to touch (winners greater)
- tackles made (winners greater)
- errors made (winners fewer)

This study illustrated that even having a larger number of positive variables (e.g. turnovers won) did not result in the team winning. However, in the same study, using the same variables but at

the international rugby level, no significant differences were found between winning and losing teams. This shows that the nuances of winning and losing may be specific for the level of rugby.

Another similar study attempted to implement a player impact ranking matrix on three Super rugby teams, looking at the individual level<sup>(80)</sup>. Although this was on an individual level, using the sum of individual scores a net game performance (NGP) score for the team predicted the score margin for all three teams (important seeing as a team from the top, middle and bottom of the log were chosen), illustrating the success of the point allocation<sup>(80)</sup>.

James *et al.* monitored the English international players over a season to determine position-specific performance indicators<sup>(81)</sup>. Their study did not relate to winning or losing or performance in any other way, and was comparing the various positions to determine the positional characteristics<sup>(81)</sup>. The variables they included however, were successful and unsuccessful tackles, successful and unsuccessful carries, successful and unsuccessful passes, handling errors, normal penalties, yellow cards, tries scored and turnovers won<sup>(81)</sup>. These variables appear frequently in the literature when performance indicators are researched, illustrating their perceived importance. However, it is important to note that owing to the contact nature of the game, players often have to play out of their designated position in a match. For example, when the players get trapped at the breakdown (ball going to ground), other players are forced to play in their position until the player is released<sup>(30)</sup>. This requires that players have to adapt to different situations making video analysis important in investigating their overall ability within a match, and not just their position specific ability.

On an international team level, a paper by Van Rooyen and Noakes examined various factors influencing the winning and losing teams in the 2003 Rugby World Cup<sup>(82)</sup>. Their study focused mainly on the playing patterns of the team participating and the teams ability to move possession from the defensive to the attacking half of the field<sup>(82)</sup>. This ability was predicted to increase the chances of a win<sup>(82)</sup>. Another finding was that teams who were ranked higher, scored more points in the second half<sup>(82)</sup>.

In summary, video analysis has proven to be very successful in predicting team and player performance. Various important factors within matches have been determined to play an

important role in producing a successful team. With this being said, however, most of the studies have been performed on professional senior teams, leaving the data available on university teams (amateur) limited.

## **Synopsis**

The Varsity Cup is a relatively new rugby union competition in which 8 teams play each other on consecutive weeks for 7 weeks. Furthermore, most of the players come from an amateur background and are unaccustomed to the high volume of training and physical stress that they are exposed to in this competition. This scenario offers a unique opportunity for examining variables that may be associated with training status, and performance in a match. Therefore the goal of this project is to track the UCT Varsity Cup Rugby players during practices and matches to determine whether there are any key performance indicators (subjective and objective) associated with individual and team performance.

## **Aims**

The first aim of this project was to measure subjective performance variables of the coaches of a university rugby union team and then relate these to the performance indicators of the performance analyst. The second aim was to determine whether the performance indicators of each player are correlated to team performance. The third aim was to investigate the various tools used to monitor training status and whether or not there are indicators which predict changes in performance.

## **Hypothesis**

The hypotheses of the study are:

The session loads and heart rate recovery measures will correlate and change according to season. The physiological and anthropometric data will predict selection and agree with previous literature regarding position (e.g. forwards heavier than backs) and seasonal changes. The subjective performance variables of the coaches will differ between the coaches and relate to performance and selection. The video analysis data will show discriminating factors between winning and losing and follow a trend.

# Methods

## Experimental Approach

The University of Cape Town Rugby Varsity Cup Team (First XV squad) were monitored from the 12<sup>th</sup> of November (beginning of Pre-Season) until the 14<sup>th</sup> of March (the completion of the 2013 Varsity Cup competition) comprising of 122 days. The players were all male and between the age of 18 and 26 years. Many variables were tested and monitored throughout this period. This was a prospective cohort study. The information was extracted and analyzed to determine relationships between variables.

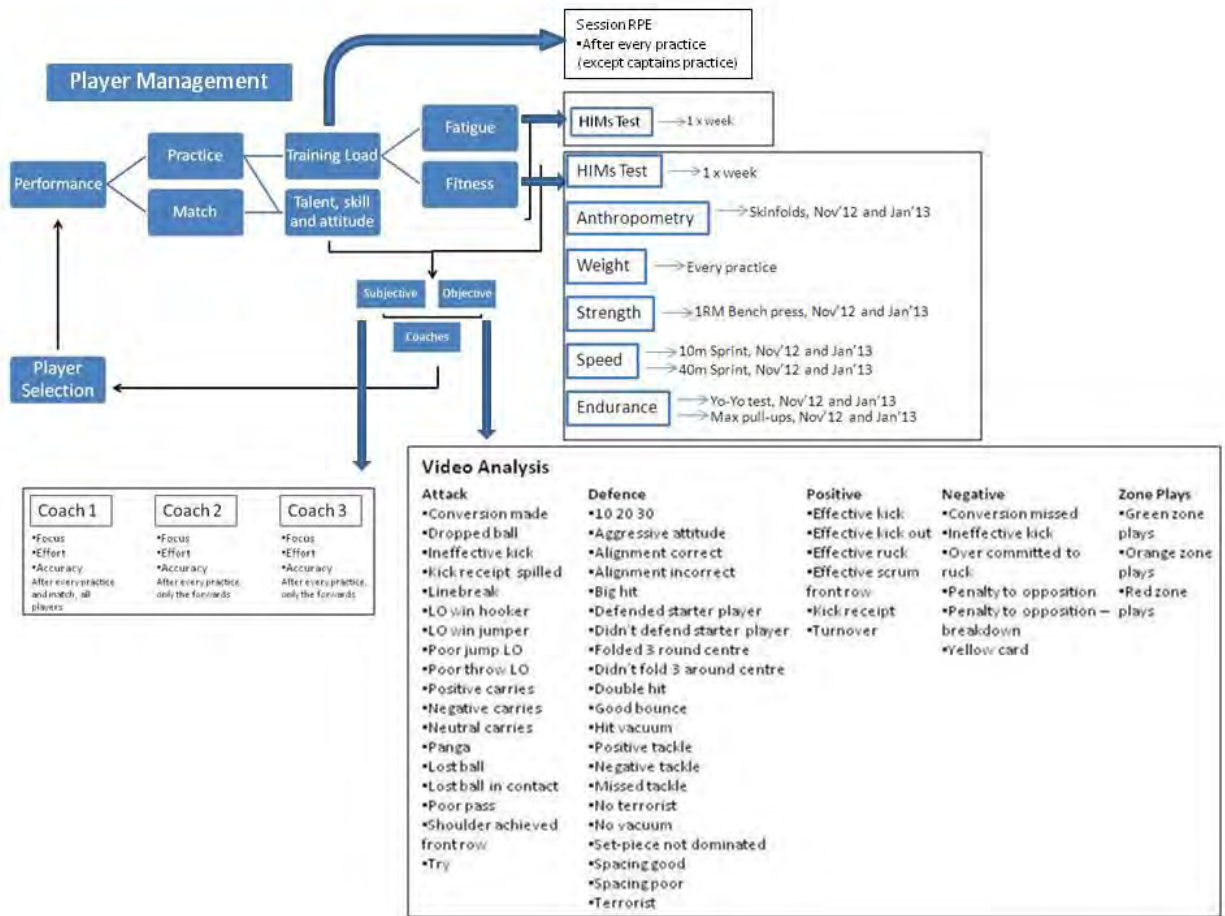


Figure 1: Schematic diagram of the data collection process.

## **Session RPE**

The players recorded their RPE regarding the practice (score out of 10) immediately after completion of practice. The duration of the practice was recorded and then the score of each individual player multiplied by the session duration to give the individual players' session RPE<sup>(83)</sup>.

## **Heart Rate Intermittent Monitoring System**

The recovery heart rate of each player was measured during the heart rate intermittent monitoring system (HIMs) test, which was done once a week (on a Thursday morning)<sup>(84)</sup>. Before the HIMs test was performed each of the players were weighed on an electronic scale (MVW Industrial Floor scale; 200kg capacity) without shoes on, but fully clothed.

### *Heart Rate Intermittent Monitoring System Protocol*

Markers were placed 20 m apart on an artificial indoor surface indicating the shuttle run. Each player wore a Suunto Heart Rate monitor belt.

1. Athletes started recording their heart rates once lined up and ready begin the test
2. Pressed play on the MP3 player containing the protocol
3. The tests consisted of 4 x 2 minute stages each separated with a 1 minute rest period
4. Each stage was progressively faster than the last (Stage 1: 8.4 Km.hr<sup>-1</sup> Stage 2: 9.6 km.hr<sup>-1</sup> Stage 3: 10.8 km.hr<sup>-1</sup> Stage 4: 12.0 km.hr<sup>-1</sup>). The speeds were predetermined by the metronome on the HIMs MP3 file.
5. During each rest period the player remained still and stood uninterrupted for the duration of the rest period.
6. Heart Rate monitor was stopped and data downloaded for analysis. The peak heart rate was taken at the end of the test and the recovery was the difference between the peak heart rate and the heart rate 1 minute post peak heart rate.

## **Weight**

The players all weighed themselves before every practice using an electronic home scale (placed on a solid flat surface). The wearing of shoes or lack thereof was not controlled.

## **Anthropometry**

### *Stature*

The measurement was recorded with the subject barefoot with his arms hanging by his sides. His heels, buttocks, upper back and head were in contact with the stadiometer (SECA Leicester 214 stadiometer). The measurement was recorded as the height from the floor to the vertex of the head. The vertex was defined as the highest point on the skull when an imaginary line between the lower margin of the eye socket and the upper margin of the zygomatic bone is parallel to the ground. The measurement was recorded at the point of deep inhalation to the nearest millimeter.

### *Sum of 4 Skinfolds*

The four skinfold sites (Triceps, Biceps, Subscapularis and Supra-iliac) were identified and clearly marked. The skinfold thickness was measured by grasping a fold of skin and the underlying subcutaneous tissue between the thumb and forefinger, 1-2 cm above the site to be measured. The fold was pulled away from the underlying muscle and the jaws of the calipers placed on either side of the site, at a depth of approximately 1 cm and at a right angle to the fold. The skinfold was held throughout the application of the caliper and the reading was recorded when the needle became steady after the full pressure of the calipers had been applied. All the measurements were taken on the right side of the player. The measurement was recorded to the nearest mm. Harpenden Skinfold Calipers (Medical Devices Directive 93/42/EEC for a class 1 Device with measuring function and is calibrated using masters traceable to National Standards) were used for all measurements. The same biokineticist trained in anthropometry performed all measurements.

The four skinfolds measured were as follows:

#### Triceps skinfold:

The fold was vertical and was measured from the posterior surface of the arm midway between the top of the shoulder (Acromion process) and the elbow (Olecranon process). The players were instructed to let their arms hang loosely by their sides while the measurement was recorded.

#### Biceps skinfold:

The measurement was recorded from the front of the subject, on the anterior surface of the arm midway between the top of the shoulder and the elbow. The arm was in the same position as for the triceps skinfold.

Subscapularis skinfold:

The player was instructed to stand with his arms at his side. The fold was taken in an oblique plane just below the inferior angle of the scapula, descending laterally and downwards at an angle of approximately 45° to the horizontal.

Supra-iliac skinfold:

The player stood with the abdominal muscles relaxed. The measurement was taken 5 cm above the iliac crest. The fold was an oblique fold descending medially and downwards at an angle of 45° to the horizontal.

*Body Fat %*

Percentage body fat was calculated from the skinfolds measurements using the *Durnin and Womersley*<sup>(55)</sup> body density equation together with the Siri equation. The *Durnin and Womersley* equation was used to estimate the body density, calculated from age (years), sum of 4 skinfold sites (Biceps, Triceps, Subscapularis and Supra-Iliac)(mm) and body mass (kg). The body density was then substituted into the Siri equation (1961) ( $Body\ Fat\ \% = 495 / Body\ Density - 450$ ) to calculate the percentage body fat.

## **Muscular Strength**

*1RM Bench press*

The one repetition maximum (1RM) bench press test was used to evaluate the player's maximal upper body strength. The test was conducted according to the National Strength and Conditioning Association (NSCA) 1RM testing protocol. According to this protocol players are supine on a bench in the five point contact position, with their feet flat on the floor and their hips and shoulders in contact with the bench. The players were instructed to grip the bar with a hand spacing of 1.5 times the biacromial width. All players completed a light warm-up including dynamic movements of the upper torso as well as set of 5 - 10 repetitions at 40-50% of their estimated 1RM. The weight was then increased to 60 - 70% of predicted 1RM and three repetitions completed. Subjects rested for five minutes before the weight was increased to the estimated 1RM. If the subject completed the repetition successfully the weight was increased by 5-10%. If the attempt was unsuccessful the weight was decreased by 2.5-5%. The next repetition was only attempted after a 4 minute rest period. The maximum weight lifted was recorded as the player's 1RM. The tester gave verbal encouragement throughout the lift. An attempt was deemed

correct if the player lifted the bar in a controlled manner and lowered the bar to the centre of his chest (lightly touching the chest), followed by extending the arms into a fully extended position. The attempted lift was disqualified if the player lifted his buttocks off the bench during the movement, if he bounced the bar off his chest, or if the spotter was required to assist in the lift.

## **Sprinting**

### *10 m and 40 m Sprint Times*

The aim of these tests were to determine the player's top end sprint time (40 m) as well as explosiveness over 10 m. Players were given a rigorous warm-up supervised by a Biokineticist. The warm-up consisted of 10 minutes of sub-maximal cycling, followed by light jogging with dynamic warm-ups and movement preparation of all major leg musculature. Players were then allowed to do two trial runs on the synthetic rubber surface for 40 m at 65% of the maximal effort and then again to the 10 m mark at 80% of the maximal effort. Players were then given 5 minutes to do additional stretching of their choice. The photoelectric sensors (Brower Speed Trap II wireless sprint system) were placed at the start line and at distances 10 m and 40 m from the start. Players were instructed to sprint maximally from a sprinter start position, for 40 m through the sensors. Each player completed two maximal effort runs separated by a 5 minute recovery period. Times were automatically recorded at 10 m and 40 m respectively.

## **Local Muscular Endurance**

### *Maximum Pull-ups*

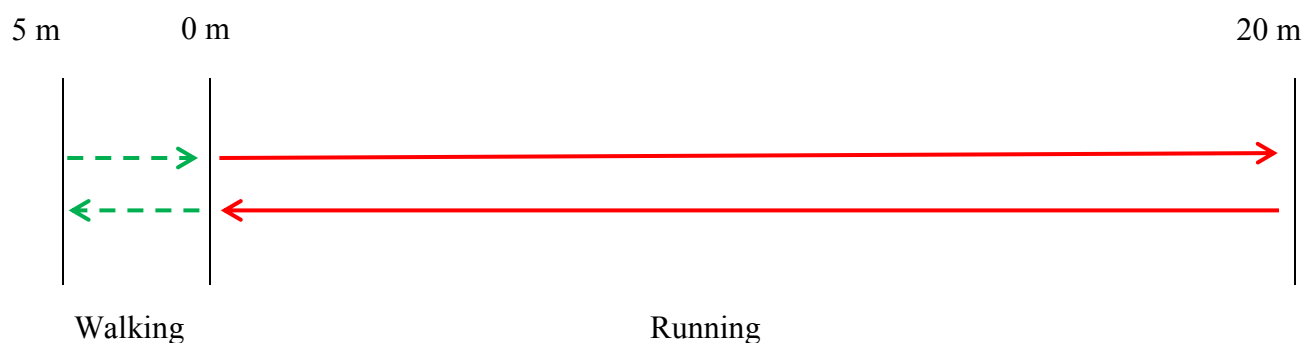
The Pull-ups test was conducted with an underhand grip and the hands 10-15 cm apart. The players started in the hanging position and ascended to a position with his chin above the bar. When returning to the starting position the arms needed to be in the fully extended position. Players were instructed to pull their knees up in the front during the movement to prevent arching of their backs. The maximal number of completed pull-ups was recorded.

## **Aerobic Endurance**

### *Yo-Yo Intermittent Recovery Test*

For the Yo-Yo test two marked lines 20 m apart were drawn on an artificial indoor surface. In addition to these lines, there was another line 5 m outside of the starting point (recovery area)<sup>(67)</sup>. The players ran out and back to the 20 m mark touching the 20 m line with one foot at the

precise moment that a sound signal was emitted from the audio CD. When returning, the athlete walked out and back to the recovery cone, 5m from the starting point. This was the procedure for each shuttle. The frequency of the sound signal increased in such a way that running speed was increased throughout the duration of the test. As the athlete ran the audio recording informed the tester at which level and shuttle the athlete was currently at. The results (total distance covered) were then looked at as the change at the beginning of pre-season and after the December vacation.



**Figure 2:** Diagram of the Yo-Yo Intermittent Recovery Test.

### Coaches' Ratings

Three coaches involved with the team of which two rated the forward players (players 1-8) and only occasionally the backs (players 9-15), whilst the one coach (the head coach) rated all the players. The three coaches rated the players on a scale of 1-5 in three categories: “focus”, “effort” and “accuracy”. This rating was performed by each coach after every practice. The head coach also rated all the players on their performance (in the same three categories) after every match (two days after the match, by which time he had also watched the video footage).

### Video Analysis

Using Sportscod Elite version 6.5.1 on an Apple Mac placed at eye level, the video analyst for the team coded variables for the match performance (variables were decided on based on the input of the coaches, video analyst and time constraints). The variables were placed into five categories: attack, defence, positive, negative and zone plays. The variables were either based on the individual player or on a team basis.

#### Attack Variables:

- Conversion made: convert kick after a try scored
- Dropped ball: player dropped ball/loses control but does not lose it either player regains possession or one of his teams mates regain possession
- Ineffective kick: kicked out on the full unintentionally – so opposition have a line-out from where ball was kicked. Or kicked in field where the opposition didn't have to move to gain possession
- Kick receipt spilled: dropped ball from a kick or kick off
- Linebreak: beat opposition in the tackle or break through the opposition defensive line
- Line-out win hooker: hooker throw in lineout was good and we win the lineout
- Line-out win jumper: jumpers jump in lineout was good, lifting was good and jumper catches the ball and wins the lineout
- Poor jump Line-out: jumpers jump in lineout was not good, lifting is poor and we lose the lineout either due to jumper dropping/knocking ball on or due to the lifting being poor
- Poor throw Line-out: we lose lineout due to poor throw from hooker either skew, over the jumper or easy for opposition to steal the lineout ball due to throw being poor
- Positive carries: ball carrier carries the ball over the gain line
- Negative carries: ball carrier does not get to gain line & loses ground or metres. Ball carrier can also have a negative carry if he is tackled behind the gain line
- Neutral carries: ball carrier carries the ball to the gain line but does not gain any metres or lose any metres
- Panga: pick ball up from a ruck & drive – pick and go from a ruck
- Lost ball: lose possession which can be from the following – knock-on, lost in contact, lost on the ground, tackled into touch
- Poor pass: pass is either too high too low or did not go directly to a team mate
- Try: we score/dot the ball down on the opposition goal area

#### Defence Variables:

- Big hit: aggressive physical tackle
- Double hit: two players made a tackle on opposition
- Positive tackle: hit opposition back in tackle or behind their gain line
- Negative tackle: made a tackle but didn't hit back, opposition makes metres

- Missed tackle: fail to make the tackle or bring opposition to ground
- Terrorist: terrorist is first player to opposition ruck to get hands on ball to turnover or steal

#### Positive Variables

- Effective Bridge: player bridged over ball at ruck to protect ball
- Effective kick: any kick that had a positive outcome for either players chancing or territory – if in open play generally an effective kick if it's made the opposition move a considerable way to receive it
- Effective kick out: self explanatory
- Effective ruck: player have made an impact at either our ruck or an opposition ruck
- Effective scrum front row: front row have effectively helped the scrum, got the shoulder and won the ball
- Kick receipt: receive a kick from opposition
- Turnover: player has either stolen ball from opposition or has capitalized on loose ball that was in opposition possession

#### Negative Variables

- Conversion missed: self explanatory
- Ineffective kick: player made a mistake by either kicking straight to opposition or kicking out on the full – resulting in loss in possession
- Penalty to opposition: referee awards a penalty to opposition because of player
- Yellow card: self explanatory

### Statistics

The parametric descriptive statistics (i.e. subject characteristics and performance variables) are represented as the mean  $\pm$  standard deviation (sd) and mean  $\pm$  95% confidence intervals (video analysis data). The non-parametric descriptive data are represented by the median and quartiles.

The coefficient of variation (CV) was calculated as  $\frac{sd}{mean}$ . The magnitude of the differences between means was represented as the effect size ( $d$ )<sup>(85)</sup> using the following

categories:  $d = 0.20 - 0.49$  small difference,  $d = 0.50 - 0.79$  medium difference and  $d > 0.80$  large difference.

Differences between positional groups were determined using an independent t-test (parametric data) and the differences in the non-parametric data were analysed using a Mann-Whitney test. The significance of physiological changes over time were determined using a paired t-test. Data that were measured throughout the season (training load, heart rate recovery and body mass) were analysed for homogeneity of variance using the Levene's test of homogeneity. Then the differences in these variables were analysed with an analysis of variance with repeated measures, with the main effects of *group* (positions) and *time* and the interaction of *group* x *time*. Relationships between variables were determined using a Pearson's correlation coefficient. All statistical analyses were done using Statistica (StatSoft, Inc., 2013, STATISTICA, version 12. www.statsoft.com.), except the correlation coefficient, for which Prism (GraphPad Prism version 5.00 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com) was used.

## Results

After the physical characteristics, the sections within the results will be presented in the same order as they were discussed in the literature review.

### Physical Characteristics

The descriptive characteristics of forwards and backs at the start of pre-pre season are shown in Table 1. As expected the forwards were significantly taller, heavier and had a higher body fat percentage than the backs.

**Table 1:** Descriptive characteristics of the forwards and backs at the start of the pre-pre-season. Mean  $\pm$  SD (n)

Variable	Forwards (n)	Backs (n)	Total (n)	p value
Stature (cm)	184.9 $\pm$ 7.4 (22)	177.6 $\pm$ 6.8 (14)	182.1 $\pm$ 7.9 (36)	0.005
Body mass (kg)	104.4 $\pm$ 9.9 (22)	82.1 $\pm$ 6.6 (14)	95.7 $\pm$ 14.0 (36)	0.001
Sum of skinfolds (mm)*	45.8 $\pm$ 17.8 (21)	28.0 $\pm$ 4.0 (14)	38.7 $\pm$ 16.5 (35)	0.001
Body fat (%)*	17.6 $\pm$ 5.2 (21)	12.1 $\pm$ 1.6 (14)	15.4 $\pm$ 4.9 (35)	0.001

\*non-parametric – Man-Whitney test

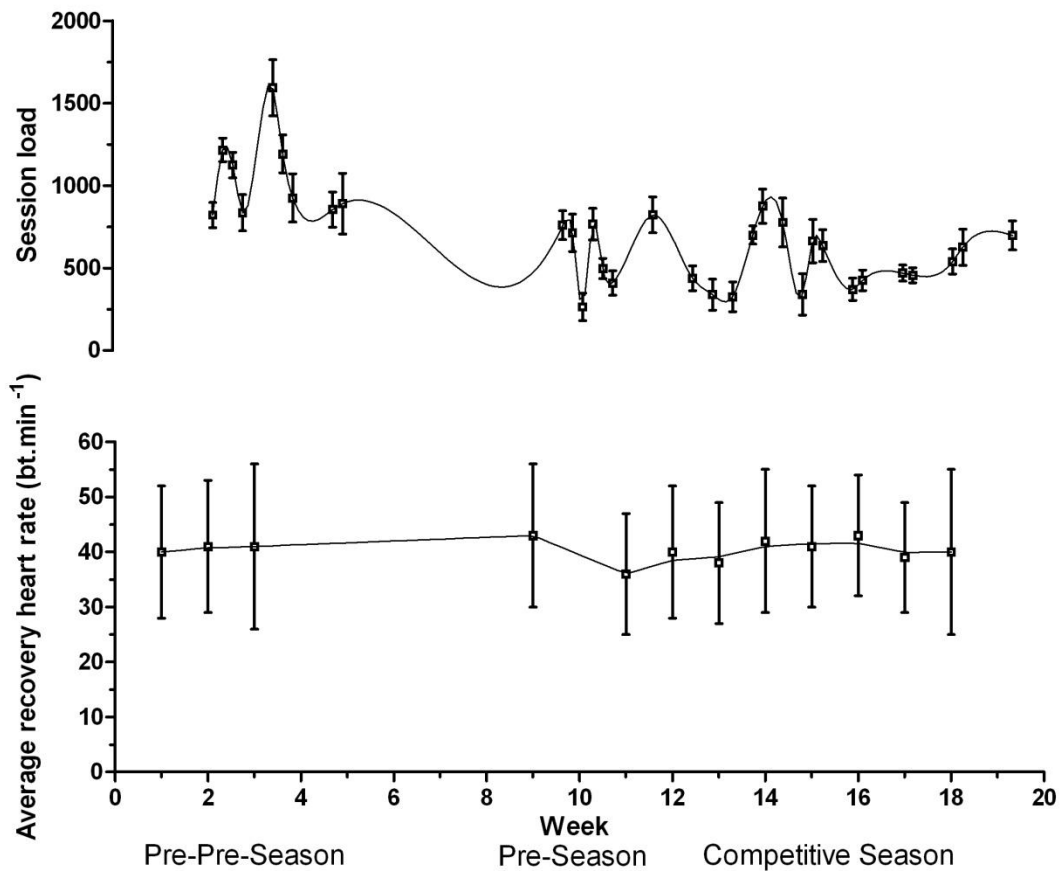
The magnitude of the differences between forwards and backs, defined by the effect size (*d*), were: stature = 0.9, body mass = 1.6, skinfolds = 1.1, body fat = 1.1, which can be interpreted as *large* differences.

### Heart Rate and Session Load

#### *Heart Rate Recovery and Session Load*

The season was divided into three parts: pre-pre-season, pre-season and the competitive season. The pre-pre-season was weeks 1-5, weeks 6-8 comprised of no training (the students were on holiday), pre-season weeks 9-11 and the competitive season was weeks 12-18. The session load averages for pre-pre-season was 1051  $\pm$  257, pre-season was 534  $\pm$  211 and the competitive season was 583  $\pm$  163 (Figure 3). The pre-pre-season session load was significantly different to

both the pre-season and competition season (pre-season and competition were not significantly different) ( $p < 0.0001$ ) when analysed using a one-way ANOVA. This is depicted in the graph, with the pre-pre-season having a visibly higher load compared to the other two parts of the season. The heart rate recovery during the HIMs test however, did not show much variation throughout the tournament regardless of the season. The sample sizes of these data varied throughout the season because the availability of the players changed through the season through injury, academic tests or personal travel.



**Figure 3:** Average recovery heart rate recovery of the team during the HIMs test each week (sample size varies between  $n=18$  to  $n=29$ ) and the average session load every practice (sample size varies between  $n=14$  and  $n=30$ ).

## Changes in Physical Characteristics: Pre-Pre-Season

Changes in body mass during the 10 weeks of pre-pre-season are shown in Table 2. Due to injury and changes in the squad, not all the players were tested in pre-pre-season and pre-season and therefore the sample size differs from Table 2. Only players involved in both phases of testing are included in the analysis. There were no significant changes in body mass in either the forwards or the backs during this phase of the season.

*Table 2: Changes in body mass during the 10 weeks of the pre-pre-season phase. Mean  $\pm$  SD*

<b>Variable</b>	<b>Forwards (n=15)</b>	<b>Backs (n=11)</b>
Body mass pre (kg)	105.3 $\pm$ 7.9	81.4 $\pm$ 7.9
Body mass post (kg)	106.0 $\pm$ 7.8	81.0 $\pm$ 7.8
Absolute change (kg)	0.8 $\pm$ 1.8	-0.3 $\pm$ 2.4
Relative change (%)	0.7 $\pm$ 1.7	-0.3 $\pm$ 3.0

Changes in the physical characteristics over the 10 weeks of pre-pre-season are shown in Table 2. Once again the sample size varies between fitness tests due to changes in squad as a result of injuries affecting the players.

**Table 3:** Changes in physical measures during the 10 weeks of the pre-pre-season phase. Mean  $\pm$  SD (n)

Variable	Forwards (n)	Backs (n)	Group	Time	Interaction
Bench press			0.017	0.459	0.004
pre (kg)	137 $\pm$ 23 (12)	120 $\pm$ 23 (7)			
post (kg)	149 $\pm$ 24 (12)	112 $\pm$ 15 (7)			
absolute (kg)	13 $\pm$ 13 (12)	8 $\pm$ 13 (7)			
relative (%)	10 $\pm$ 10 (12)	5 $\pm$ 9 (7)			
Pull-ups			0.066	0.231	0.484
pre	14 $\pm$ 5 (13)	18 $\pm$ 4 (8)			
post	14 $\pm$ 7 (13)	20 $\pm$ 5 (8)			
absolute	1 $\pm$ 4 (13)	2 $\pm$ 6 (8)			
relative (%)	2 $\pm$ 23 (13)	16 $\pm$ 36 (8)			
Speed 10 m			0.044	0.183	0.891
pre (s)	1.7 $\pm$ 0.1 (11)	1.6 $\pm$ 0.1 (9)			
post (s)	1.7 $\pm$ 0.1 (11)	1.7 $\pm$ 0.0 (9)			
absolute (s)	0.0 $\pm$ 0.1 (11)	0.0 $\pm$ 0.0 (9)			
relative (%)	1.4 $\pm$ 5.8 (11)	1.6 $\pm$ 1.2 (9)			
Speed 40 m			0.004	0.012	0.811
pre (s)	5.4 $\pm$ 0.3 (11)	5.1 $\pm$ 0.1 (9)			
post (s)	5.4 $\pm$ 0.2 (11)	5.1 $\pm$ 0.1 (9)			
absolute (s)	0.1 $\pm$ 0.1 (11)	0.1 $\pm$ 0.1 (9)			
relative (%)	1.4 $\pm$ 2.5 (11)	1.2 $\pm$ 1.0 (9)			
Yo-Yo test			0.001	0.001	0.098
pre (m)	1218 $\pm$ 288 (11)	1797 $\pm$ 271 (7)			
post (m)	1553 $\pm$ 352 (11)	2520 $\pm$ 614 (7)			
absolute (m)	335 $\pm$ 264 (11)	723 $\pm$ 664 (7)			
relative (%)	29 $\pm$ 25 (11)	44 $\pm$ 46 (7)			

These physical measures (as mentioned in Table 3), are explained by the main effects of positional groups (i.e. forwards and backs) and time (pre-pre-season and pre-season), and the interaction between positional groups and time. For bench press the two groups were significantly different, however the change over time was not significant. There was a significant interaction of positional group and time suggesting the groups responded differently over time. This is shown in Table 3, where the average increase of the forwards was 12 kg compared to the backs who decreased by 8 kg.

Although there were no significant differences between groups ( $p = 0.066$ ) for pull-ups, (Table 3), the effect size ( $d = 0.7$ ) was classified as *medium*. The number of pull-ups the players were

able to do over this period did not change (Table 3). The backs were faster than the forwards over 10 m ( $d = 1.0$ ), but neither group changed their 10 m sprinting speed over this phase of the season (Table 3).

In contrast to the performance in the 10 m sprint, the players were faster in the 40 m sprint at the end of the phase of training when compared to the beginning ( $p = 0.012$ ) (Table 3). The forwards improved their time by  $1.4 \pm 2.5\%$  whereas as the backs improved by  $1.2 \pm 1.0\%$  (Table 3). As expected the backs were consistently faster than the forwards.

The backs performed better in the Yo-Yo test than the forwards ( $p = 0.001$ ) ( $d = 1.5$ , which can be interpreted as a *large* difference) (Table 3). Both groups changed similarly over time ( $29 \pm 25\%$  vs.  $45 \pm 46\%$ ; forwards vs. backs).

### Relationships between Physiological Characteristics and the Corresponding Changes over Pre-Pre-Season and Pre-Season

The correlations between the various physiological characteristics of the players tested during the pre-pre-season are shown in Table 4. The correlations in bold are statistically significant ( $p < 0.05$ ).

**Table 4:** Correlations of physiological characteristics of the players.

	Body mass	Stature	Sum of skinfolds	Body fat	Bench press	Pull-ups	Speed 10 m	Speed 40 m	Yo-Yo level
Body mass	1.00	<b>0.60</b>	<b>0.69</b>	<b>0.68</b>	0.13	<b>-0.55</b>	<b>-0.51</b>	<b>-0.73</b>	<b>-0.65</b>
Stature	<b>0.60</b>	1.00	0.22	<b>0.35</b>	-0.28	-0.27	0.02	-0.20	-0.28
Sum of skinfolds	<b>0.69</b>	0.22	1.00	<b>0.96</b>	-0.14	<b>-0.72</b>	<b>-0.67</b>	<b>-0.80</b>	<b>-0.62</b>
Body fat	<b>0.68</b>	<b>0.35</b>	<b>0.96</b>	1.00	-0.18	<b>-0.73</b>	<b>-0.58</b>	<b>-0.75</b>	<b>-0.60</b>
Bench press	0.13	-0.28	-0.14	-0.18	1.00	0.16	-0.18	-0.20	-0.16
Pull-ups	<b>-0.55</b>	-0.27	<b>-0.72</b>	<b>-0.73</b>	0.16	1.00	0.15	<b>0.37</b>	<b>0.40</b>
Speed 10 m	<b>-0.51</b>	0.02	<b>-0.67</b>	<b>-0.58</b>	-0.18	0.15	1.00	<b>-0.87</b>	<b>0.42</b>
Speed 40 m	<b>-0.73</b>	-0.20	<b>-0.80</b>	<b>-0.75</b>	-0.20	<b>0.37</b>	<b>-0.87</b>	1.00	<b>0.56</b>
Yo-Yo level	<b>-0.65</b>	-0.28	<b>-0.62</b>	<b>-0.60</b>	-0.16	<b>0.40</b>	<b>0.42</b>	<b>0.56</b>	1.00

*The sample size varied between 17 and 26. Time for 10 m and 40 m were converted into average speed.*

Body mass at the start of pre-pre-season training had a significant positive correlation with stature, sum of skinfolds, body fat, but decreased their average speed (10 m and 40 m)(Table 4).

Also, the heavier players generally had an associative lower number of pull-ups and lower level in the Yo-Yo test. The taller players (stature) were associated with a higher percentage of body fat.

Players with an increased sum of skinfolds had increased body fat percentage (as expected since sum of 4 skinfolds are used to calculate body fat %), slower average speed (both 10 m and 40 m), performed fewer pull-ups and reached lower Yo-Yo levels (Table ). There was also an inverse relationship between body fat percentage and pull-ups and Yo-Yo level, and similarly slower performances in the 10 m and 40 m sprints (Table 4).

Performance in the bench press was not associated with any of the variables (Table 4).

There was a relationship between the number of pull-ups and both faster performance in the 40 sprint test, and also a higher performance in the Yo-Yo test (and by implication increased aerobic fitness) (Table 4).

The correlations in physiological characteristics of the players are shown in Table 4. The increase in 10 m speed accounted for decrease in 40 m speed. As the players got faster in the 10 m and 40 m, their performance in the Yo-Yo test decreased, indicating decreased aerobic fitness (Table 4).

After the pre-pre-season training the testing battery was performed again (at the beginning of the pre-season) (Table 4). The relative changes for these variables indicated new correlations between variables and their effects on one another (Table 5).

**Table 5:** Correlations between the relative changes in physiological characteristics of the players from pre-pre-season to pre-season.

		%Δ							
		Body mass	Sum of skinfolds	Body fat	Bench press	Pull ups	Speed 10 m	Speed 40 m	Yo-yo level
%Δ	Body mass	1.00	<b>0.54</b>	<b>0.56</b>	0.02	<b>-0.45</b>	0.08	0.11	0.21
	Sum of skinfolds	<b>0.54</b>	1.00	<b>0.99</b>	-0.80	-0.22	-0.05	-0.11	<b>0.48</b>
	Body fat	<b>0.56</b>	<b>0.99</b>	1.00	-0.12	-0.20	-0.05	-0.10	0.46
	Bench press	0.02	-0.80	-0.12	1.00	-0.21	0.06	-0.13	0.13
	Pull ups	<b>-0.45</b>	-0.22	-0.20	-0.21	1.00	0.07	0.09	-0.20
	Speed 10 m	0.08	-0.05	-0.05	0.06	0.07	1.00	<b>-0.89</b>	0.14
	Speed 40 m	0.11	-0.11	-0.10	-0.13	0.09	<b>-0.89</b>	1.00	0.21
	Yo-yo level	-0.21	<b>-0.48</b>	-0.46	-0.13	0.20	0.14	0.21	1.00

The sample size varied between 17 and 26.

Bold values denote  $p < 0.05$ .

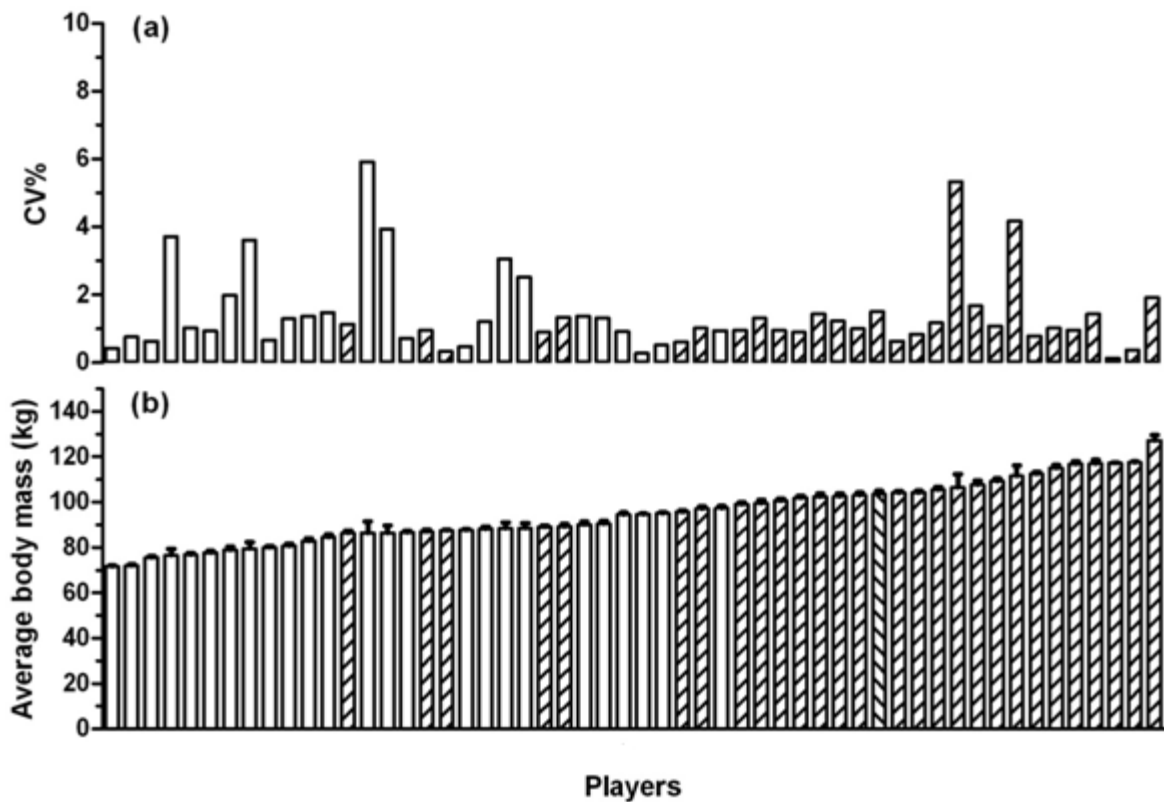
There was an association between an increased body mass, increased sum of skinfolds and body fat and a decreased number of pull-ups (Table 5). The increase in sum of skinfolds was also associated with an increased body fat percentage and a lower level in the Yo-Yo test.

Changes in bench press were not associated with changes in any other variable (Table 5). With regards speed, changes in 10 m speed were inversely related to changes in the 40 m speed.

## Body Mass Variation

### *Average Player Body Mass*

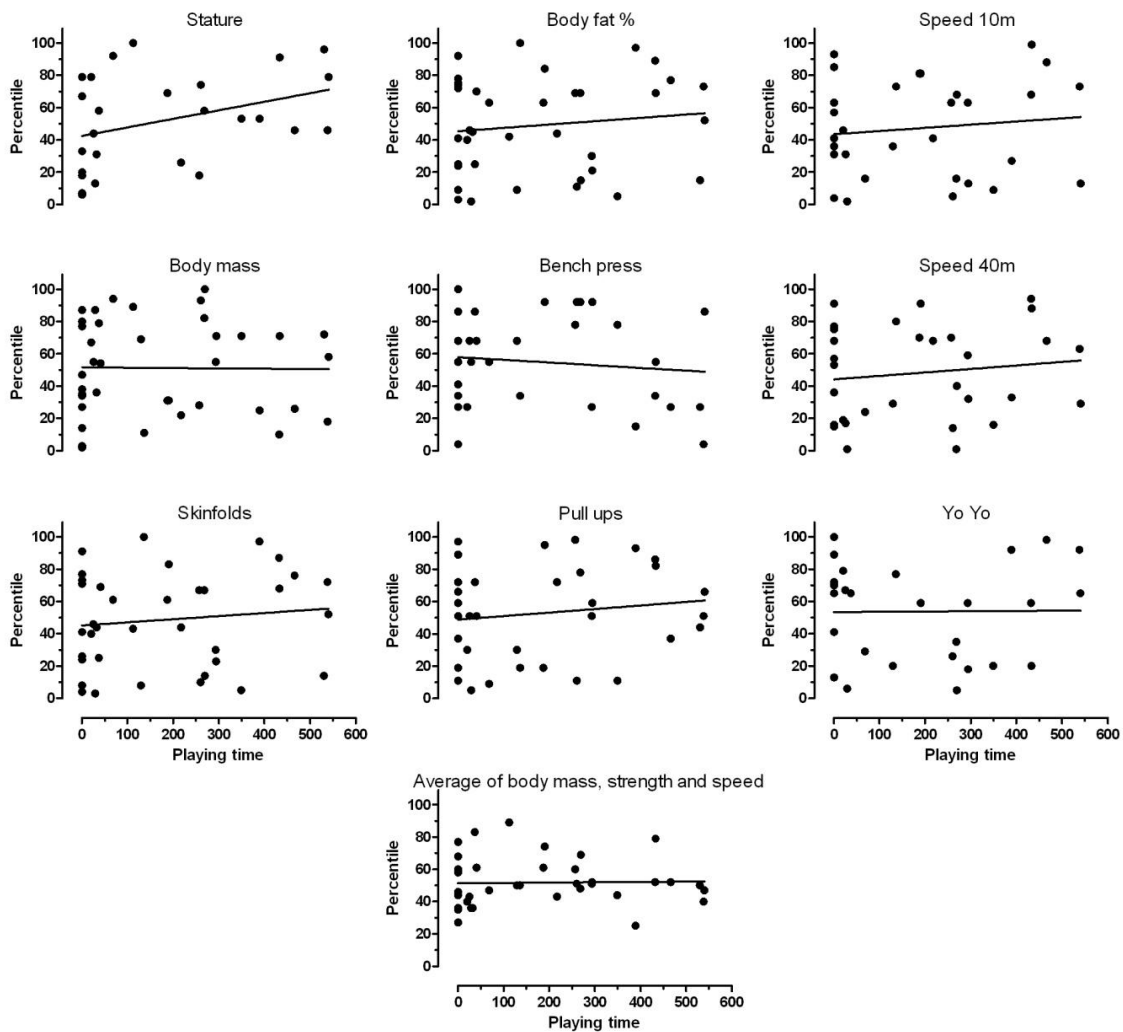
The players were weighed at every practice. The average weight of each player over the entire season is shown in Figure 4. The coefficient of variation (CV), which indicates the percentage fluctuation in body mass over the season, was also calculated for each player. The average CV for the forward players was  $1.3 \pm 1.1\%$ , compared to the backs with an average of  $1.6 \pm 1.4\%$ . This difference was not significant. The individual CVs ranged from 0.1 to 5.9%. Figure 4 shows that there is no pattern of the heavier players having more variation in body mass.



**Figure 4:** (a) Average body mass of each player over the course of the season. (b) The coefficient of variation (CV) for each player. (Blank bars represent backline players, striped bars represent forwards)(n=54)

## Physiological Variables and Playing Time

The players within the group were ranked according to their performance in each test conducted at the start of the season and these rankings were converted into percentiles. The percentile scores for each variable were then plotted against the total playing time in the season (Figure 5).



**Figure 5:** Correlation between the initial testing battery percentile of a player and the number of minutes played during the tournament (sample size varies between  $n=26$  and  $n=38$ ).

There was no correlation between the ranking of the individual characteristics and the total number of minutes played by the players throughout the tournament (Figure 5). Although the total playing time can be regarded as a proxy measure for performance, there are limitations in

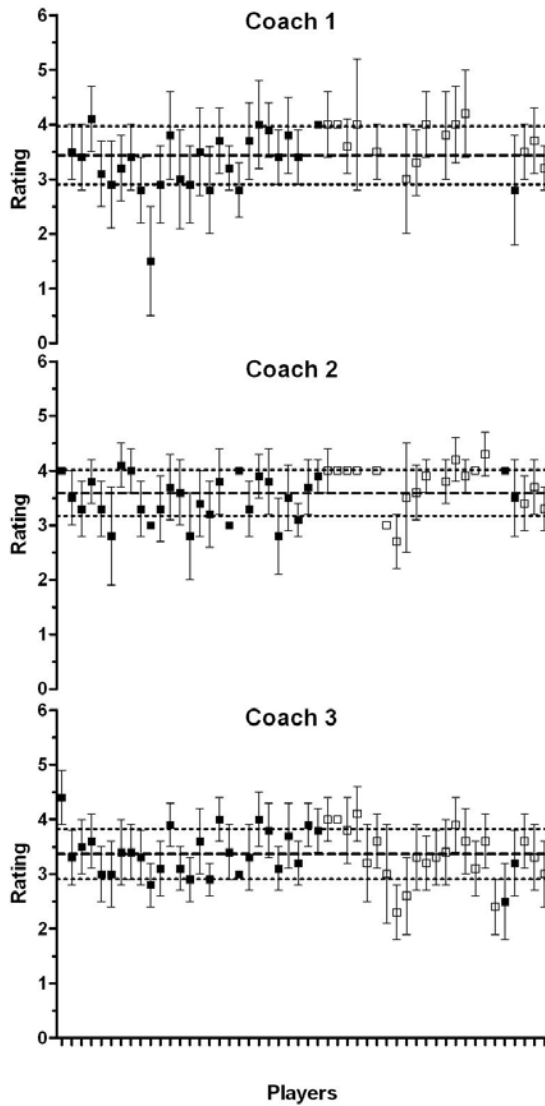
this approach as some of these players did get injured within the tournament, thus limiting the number of minutes they could play.

## **Coaches' Ratings**

### *Coaches' Average Ratings over the Season*

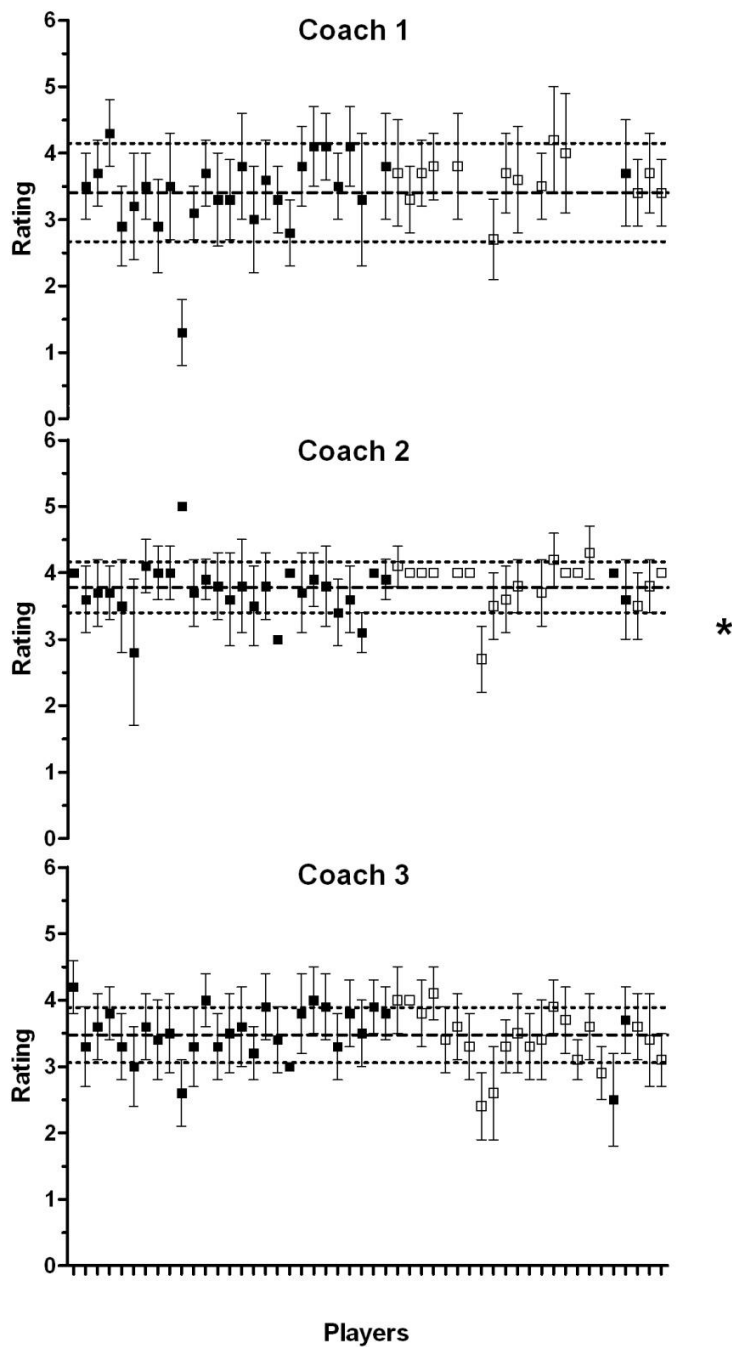
Figure 6 shows a summary of the coaches' evaluation of the players (backs and forwards) after each practice during the pre-season and competition phase of the tournament. The players (backs: unfilled symbols, and forwards: closed symbols) were rated for "accuracy" (Figure 6 (a)), "effort" (Figure 7 (b)) and "focus" (Figure 8 (c)) by the three coaches.

### (a) Accuracy



**Figure 6:** (a) Average “accuracy” ratings of the three coaches for each player over the season. The dotted lines represent the mean and standard deviations (positive and negative). (Unfilled data points represent backs, filled data points represent forwards) ( $n=50$ )

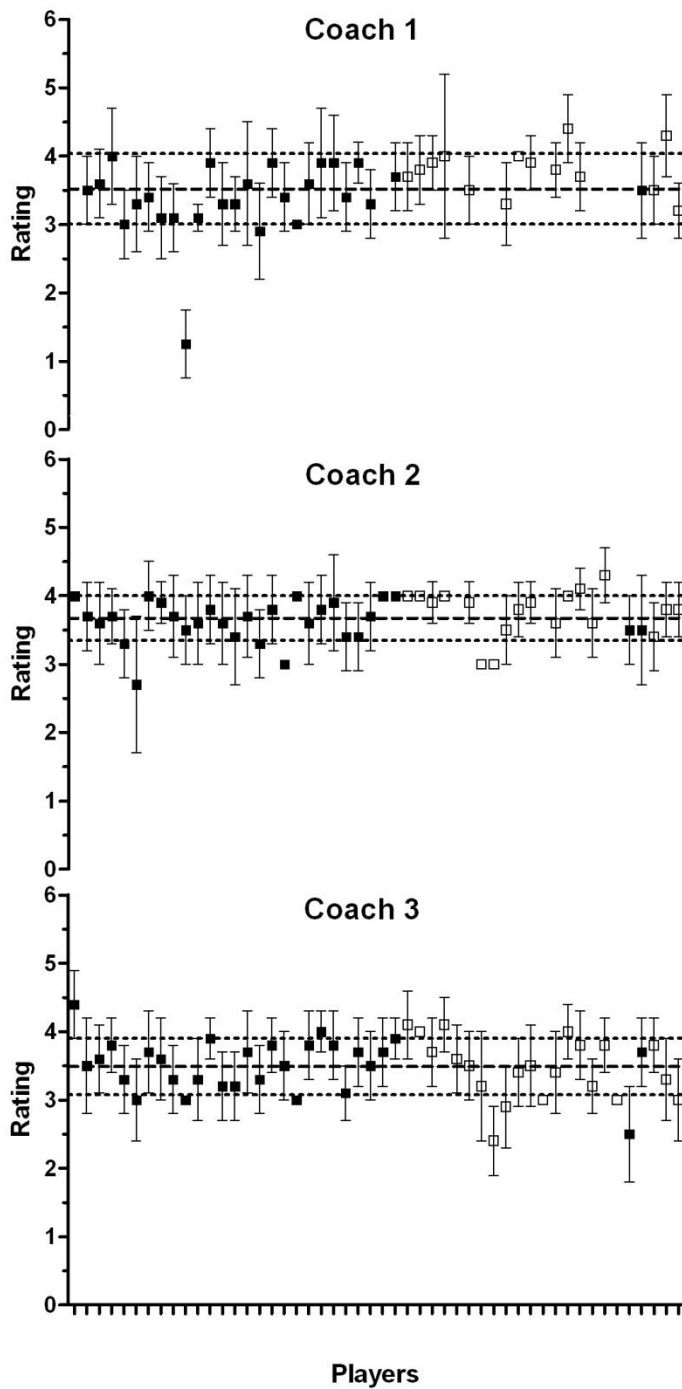
## (b) Effort



**Figure 7:** (b) Average “effort” ratings of the three coaches for each player over the season. The dotted lines represent the mean and standard deviations (positive and negative). (Unfilled data points represent backs, filled data points represent forwards) ( $n=50$ )

(\* Coach 2 was significantly different to both Coach 1 and Coach 3,  $p=0.002$ ).

### (c) Focus



**Figure 8:** (c) Average “focus” ratings of the three coaches for each player over the season. The dotted lines represent the mean and standard deviations (positive and negative). (Unfilled data points represent backs, filled data points represent forwards) (n=50)

### (d) Accuracy

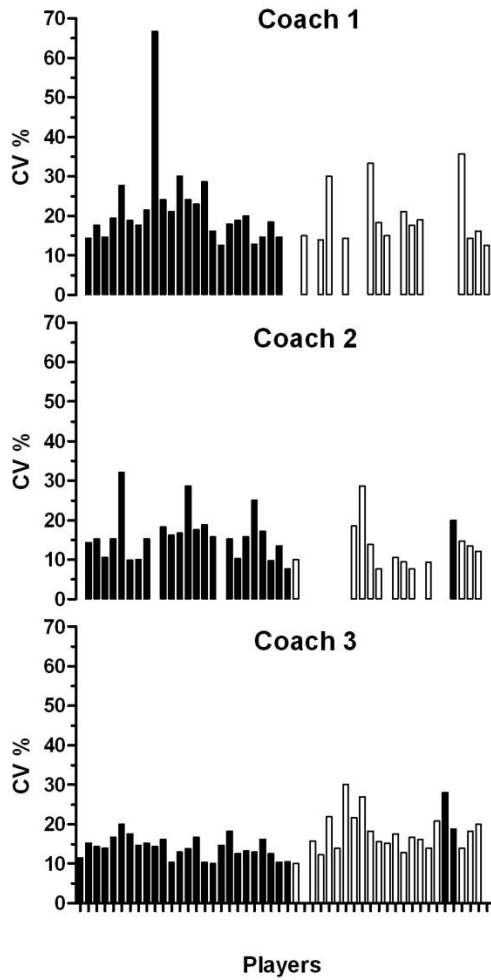
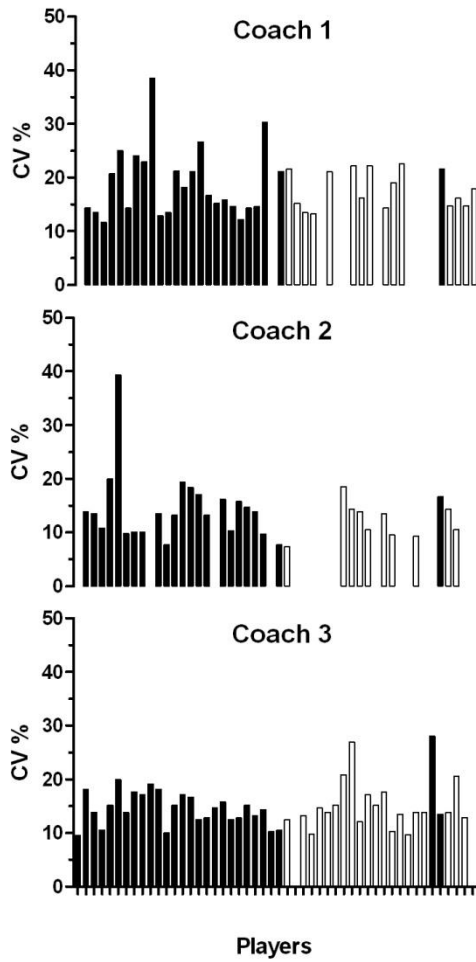


Figure 9: (d) Coefficient of variation (CV) for each coach for “accuracy”.

## (e) Effort



*Figure 10: (e) Coefficient of variation (CV) for each coach for “effort”.*

## (f) Focus

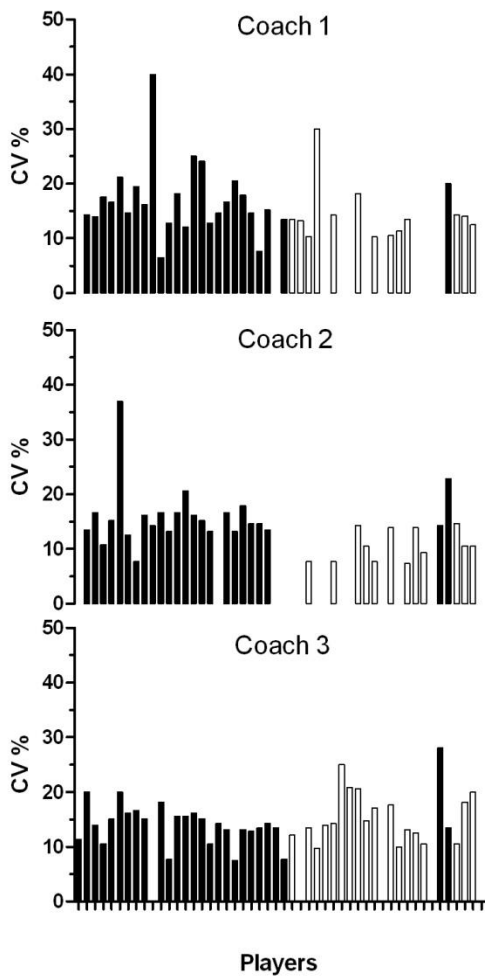
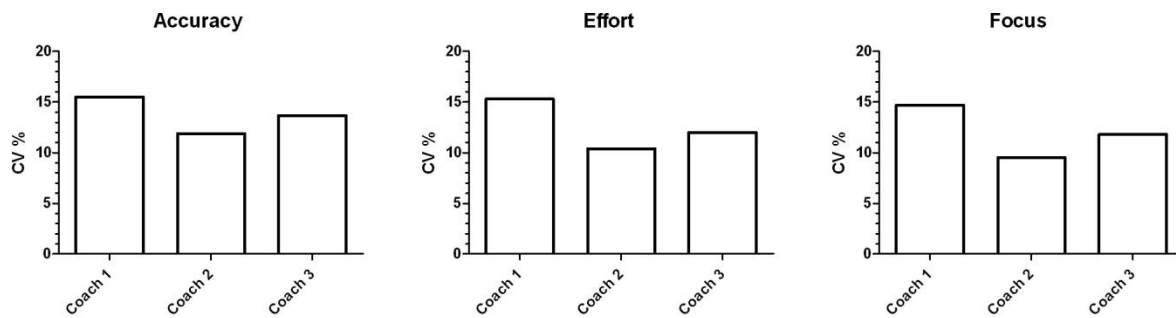


Figure 11: (f) Coefficient of variation (CV) for each coach for “focus”.

(g)



**Figure 12:** (f) Average coefficient of variation (CV) for each coach for “accuracy”, “effort” and “focus”.

The coaches all had similar ratings for the players in the “accuracy” and “focus” categories (Figure 6 (a), 7 (b), 8 (c)); however Coach 2 rated the players significantly differently in the “effort” category when compared to both Coach 1 and Coach 3. It must be noted that Coach 3 was the head coach and always rated every player, whilst Coach 1 and Coach 2 were both forwards coaches, and only occasionally rated the backline players when they had observed the backline players for a long period of the practice. The coefficient of variation for each coach for each variable (“accuracy”, “effort”, “focus”) is also important to note, to put the changes in ratings into perspective. Coach 1 had the highest CV of all the coaches in all three categories (Figure 12 (g)).

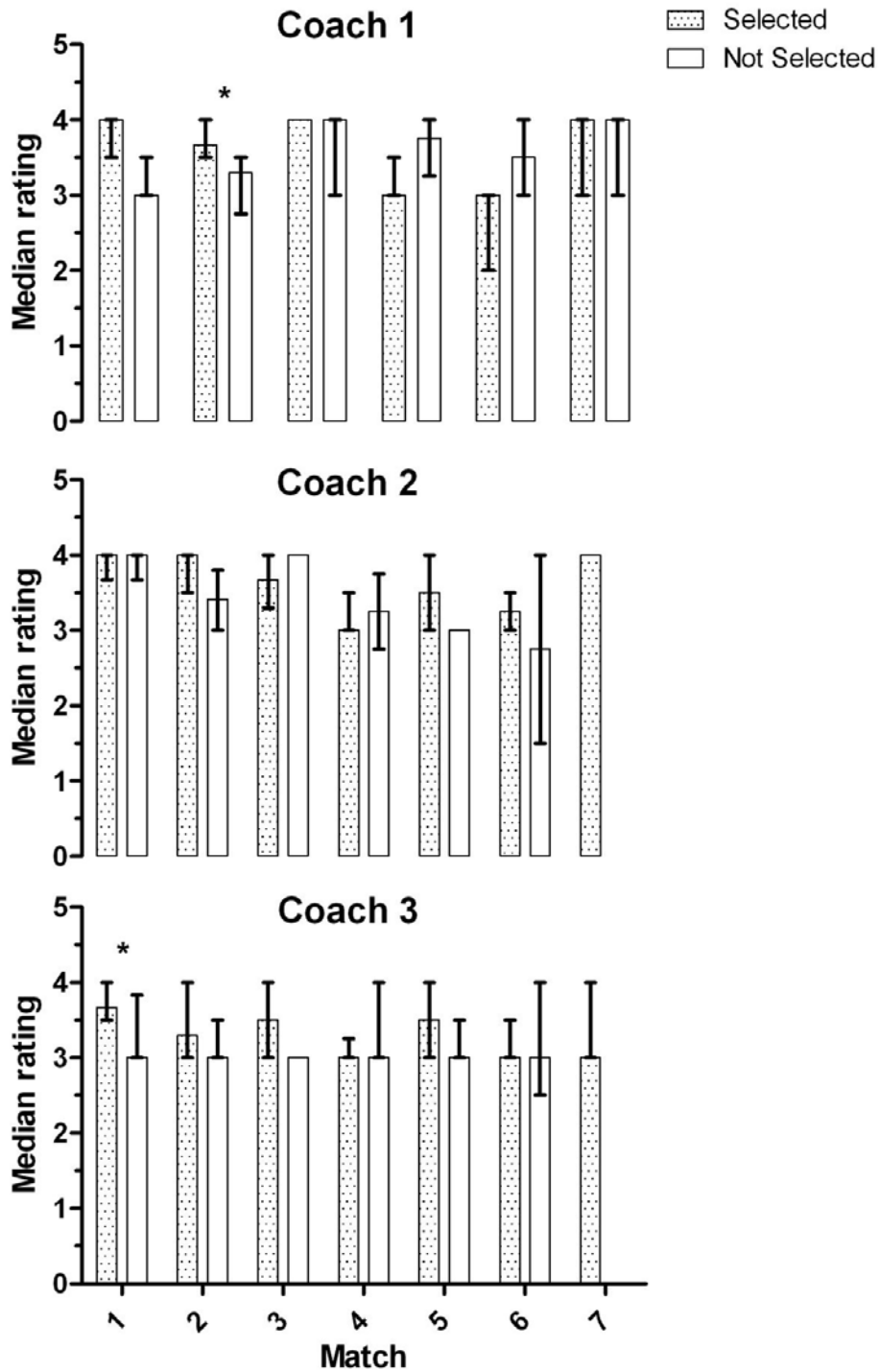
### *Coaches' Ratings Regarding Selection and Non-Selection*

The ratings for “accuracy”, “effort” and “focus” of the three coaches for the players selected for a match, and those not selected for a match are shown in Figure 13 (a), 14 (b), 15 (c). The ratings are classified as medians and upper and lower quartiles due to the small sample size, and thus non-parametric statistics (including a Wilcoxon matched-pairs signed rank test) were performed. It should be noted that the quartiles and medians are visually misleading due to non-parametric statistics. However, for “accuracy”, Coach 1 had a significant difference in match two ( $p < 0.05$ ), whereas Coach 3 had a significant difference in match one ( $p < 0.05$ ), and Coach 2 had no significant differences between players selected vs. players not selected (Figure 13 (a)).

For “effort”, there were no significant differences between the selected and non-selected players for any of the matches (Figure 14 (b)).

For the final category of “focus”, there was a significant difference in match one ( $p < 0.01$ ) and match two ( $p < 0.05$ ) for Coach 1. There were no differences for either Coach 2, or Coach 3 (Figure 15 (c)).

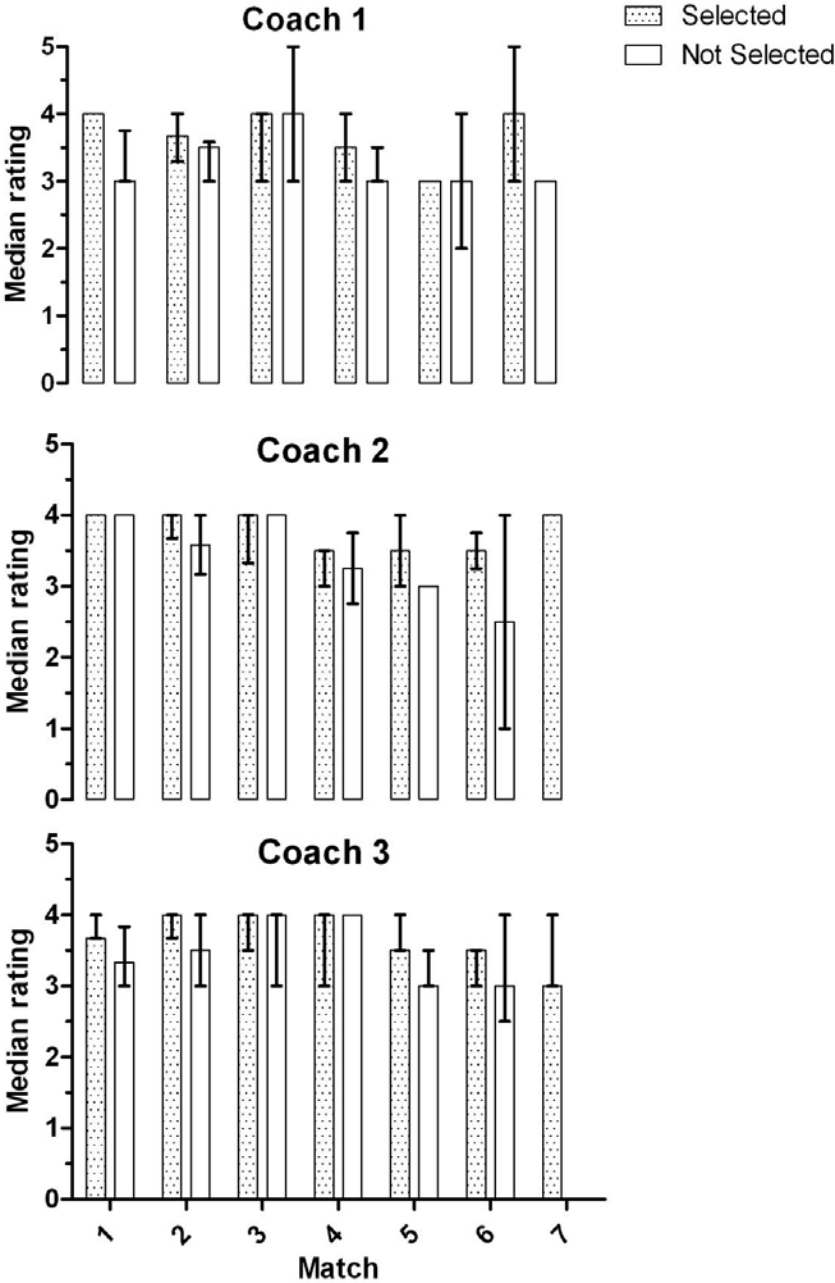
### (a) Accuracy



**Figure 13:** (a) Median rating of “accuracy” of each coach for the selected and non-selected players for the week preceding the match (including quartiles).

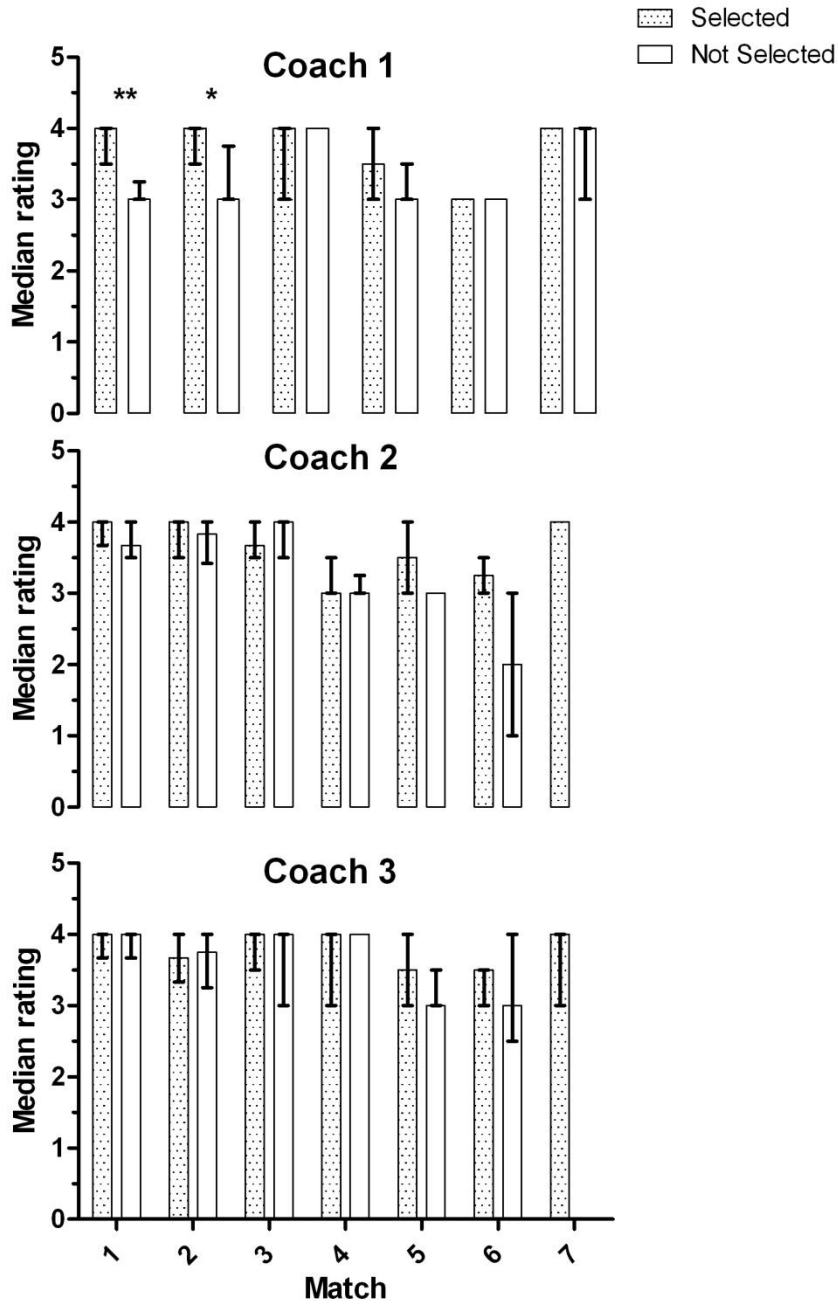
\*( $p < 0.05$ )

**(b) Effort**



*Figure 14: (b) Median rating of “effort” of each coach for the selected and non-selected players for the week preceding the match (including quartiles).*

**(c) Focus**

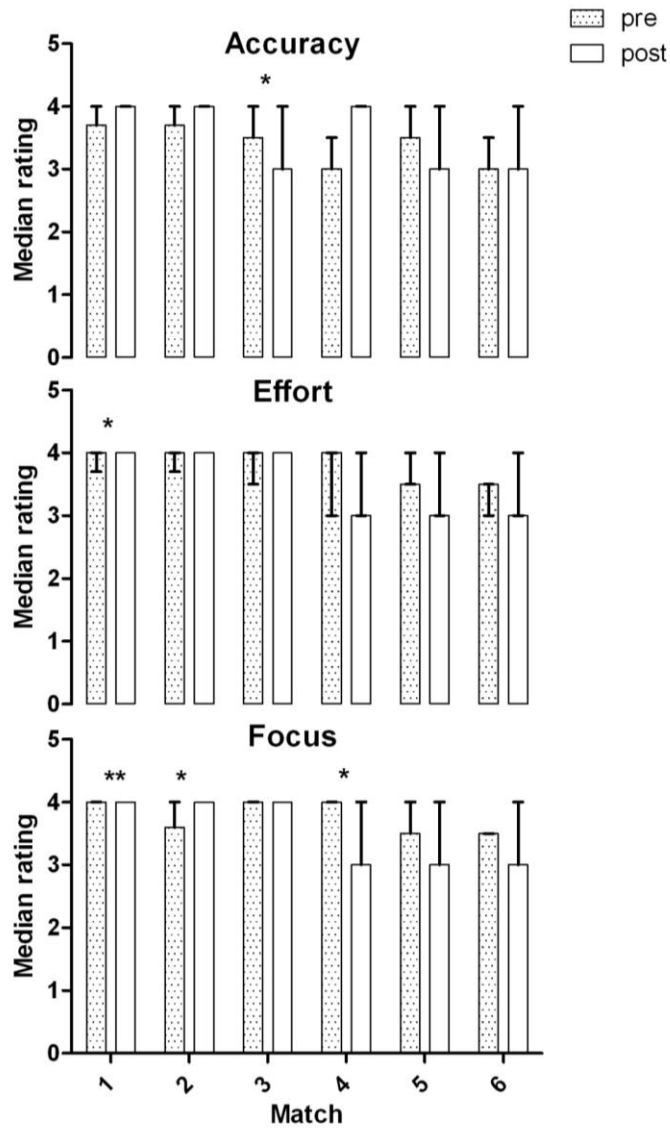


*Figure 15: (c) Median rating of “focus” of each coach for the selected and non-selected players for the week preceding the match (including quartiles).*

*\*(p<0.05) \*\*(p<0.01)*

### *Coach 3 (Head Coach) Pre- and Post-Match Ratings*

Coach 3 (head coach) rated the players after each match (after watching the video analysis footage). Figure 16 shows the relationship between Coach 3's score for "accuracy", "effort" and "focus" measured before the match, compared to the score after the match by the same coach (Figure 16). Due to sample size and distribution, non-parametric statistics were performed. The pre-match rating is an average of the week's practice ratings leading up to the match. For "accuracy", a significant difference was found in match three ( $p < 0.05$ ), whilst there was a significant difference for "effort" in match one ( $p < 0.05$ ), and for "focus" also in match one ( $p < 0.01$ ), match two ( $p < 0.05$ ) and match four ( $p < 0.05$ ). There were seven matches played in the tournament, however Coach 3 was unavailable to rate the players in the final match.

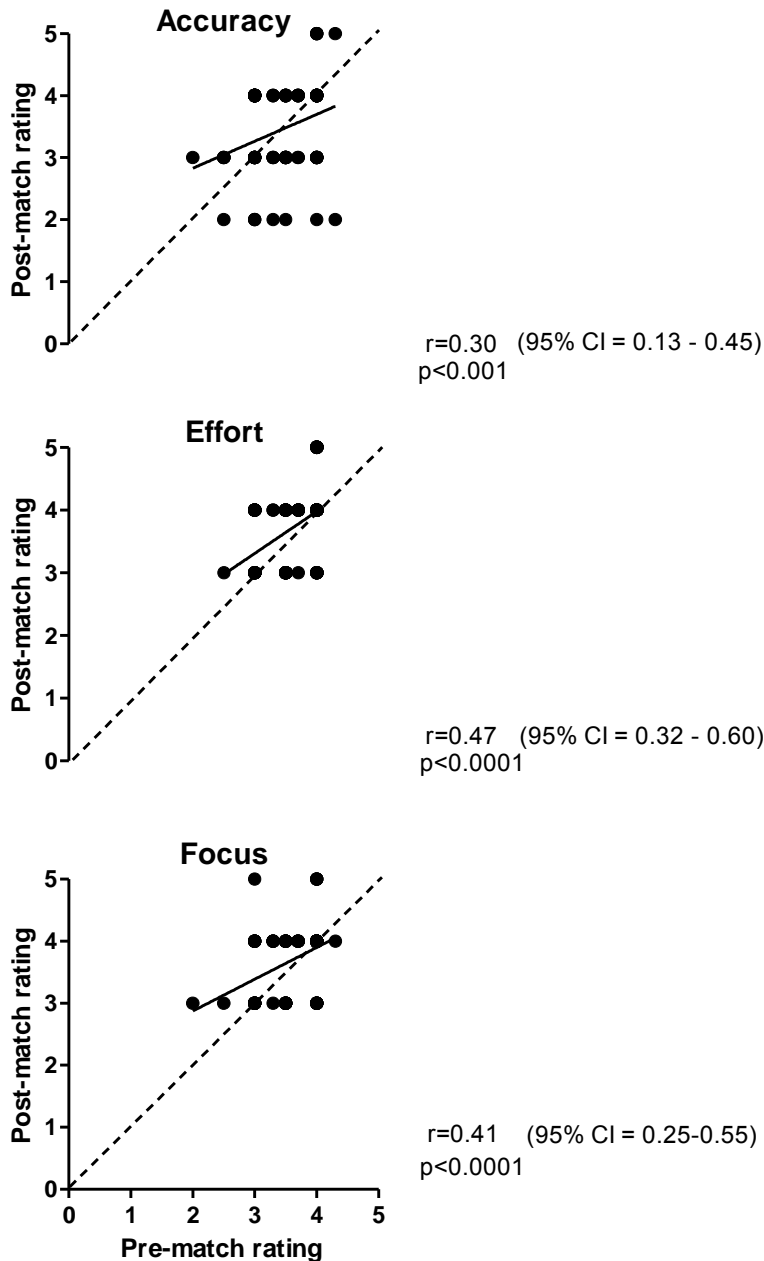


**Figure 16:** Coach 3's median player ratings pre- and post-match (including quartiles)(n=33).

\*( $p < 0.05$ ) \*\*( $p < 0.01$ )

Using the ratings from Figure 16, the pre- and post-match ratings were plotted (Figure 17). It should be noted that there are approximately 122 data points per graph, but many of these are superimposed in the figures, creating the impression that there are not that many.

## Ratings pre- and post-match (coach 3)



*Figure 17: Coach 3's ratings pre- and post-match (n=122). The dotted line represents the line of identity.*

The linear plot of pre-match versus post-match ratings of coach 3 illustrated the significant positive relationship between the perceived performances of the players (pre- and post-match) in

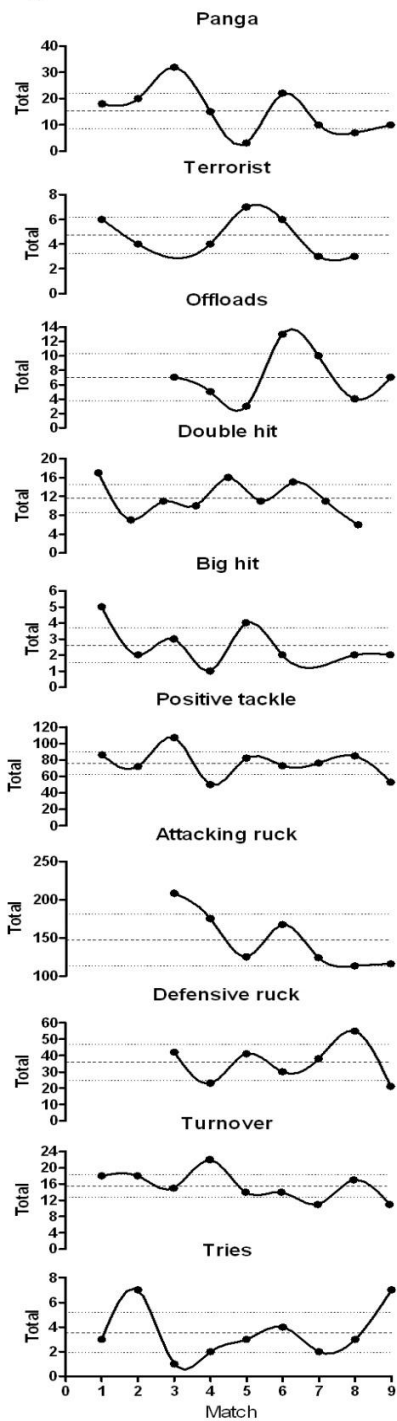
all categories. “Effort” showed the largest correlation between pre- and post-match ratings, whereas “accuracy” had the least. For “accuracy”, the relationship shows that 9% of the change in pre-match rating was accounted for by the post-match rating (using the  $R^2$  value), leaving 91% unaccounted for. However when looking at “effort”, 22% is accounted for, and for “focus” only 17%.

## **Video Analysis**

Video analysis was performed for all of the nine matches played by the team. There was much fluctuation in the total of the positive variables depending on the match, as well as between the variables. There was no visible trend in any of the variables. Any value lying outside of the confidence interval for that particular variable was deemed exceptional; either a positive exception or a negative exception.

Video Analysis Variables

(a)



(b)

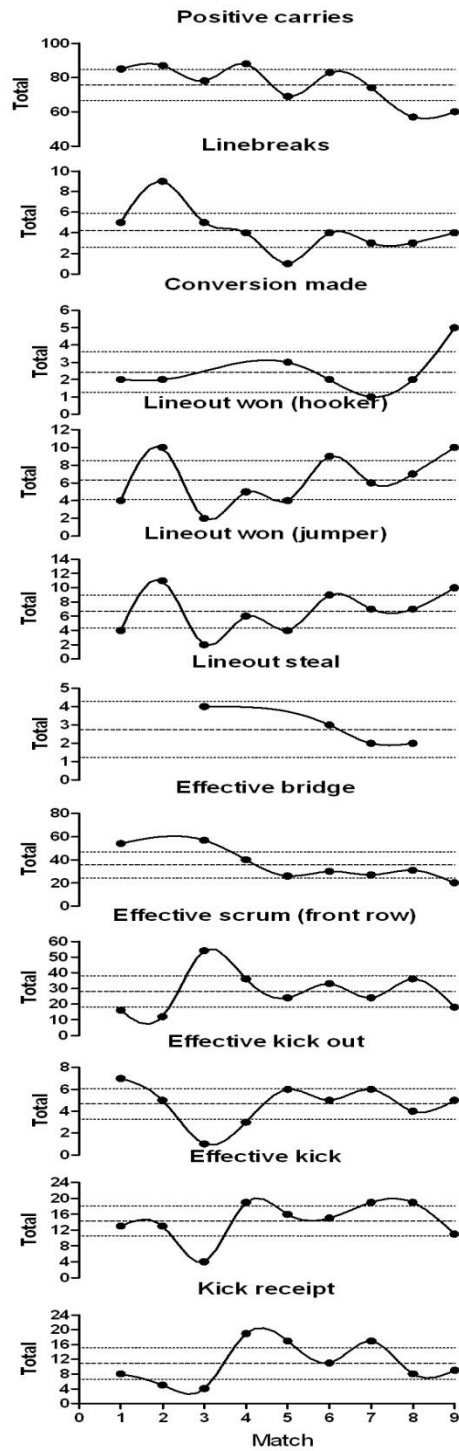
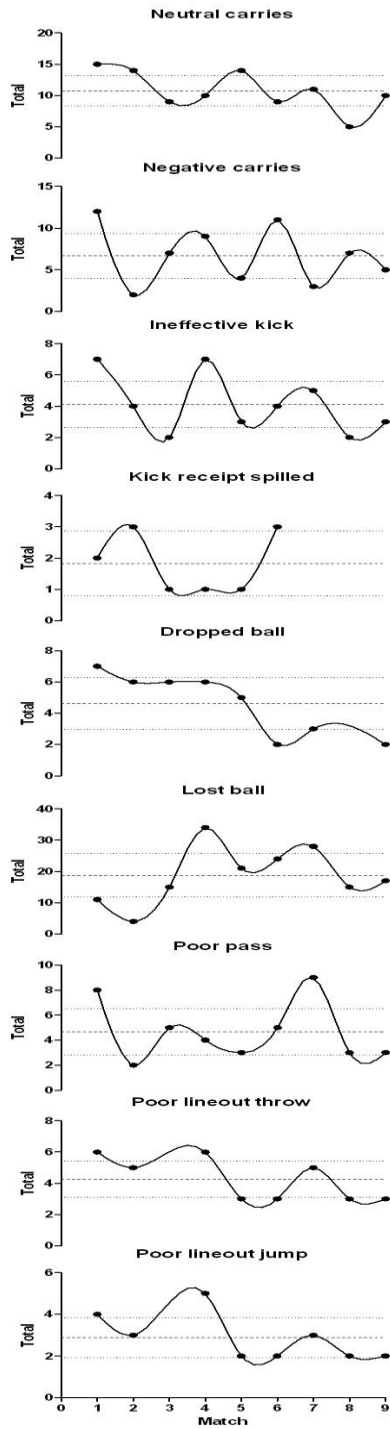
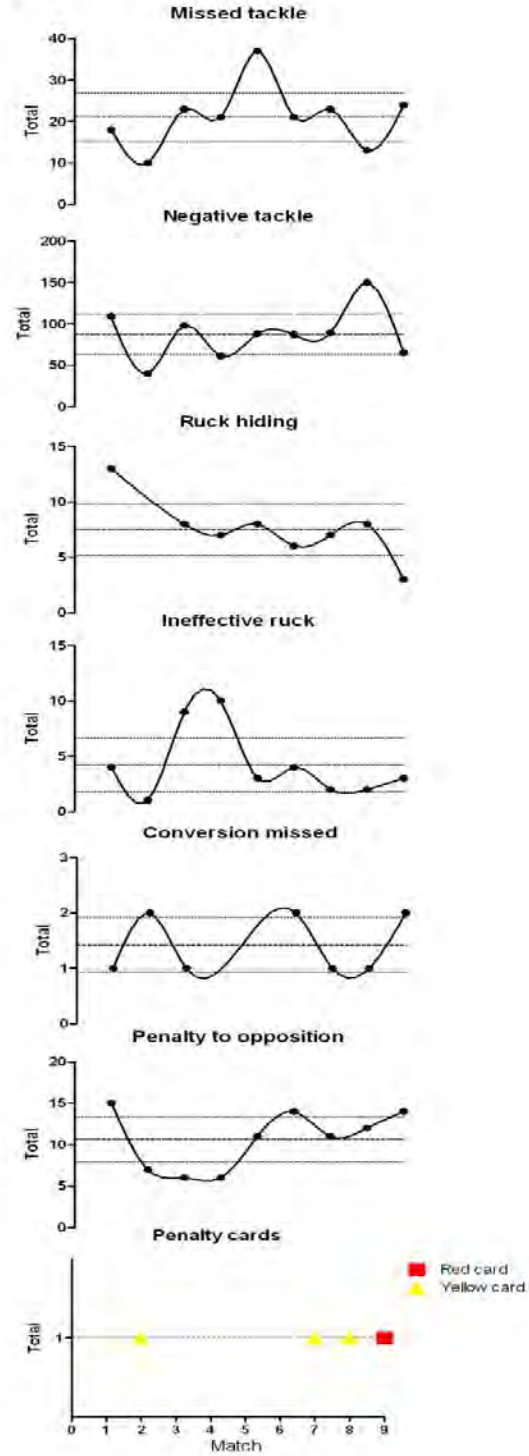


Figure 18: (a) and (b) Positive video analysis variables as a total per match (including the two warm-up matches)(sample size varies from  $n=8$  to  $n=1028$ ). Mean and the 95% Confidence Intervals are illustrated by gridlines.

(a)



(b)



**Figure 19:** (a) and (b) Negative video analysis variables as a total per match (including the two warm-up matches) (sample size varies from  $n=3$  to  $n=787$ ). Mean and the 95% Confidence Intervals are illustrated by gridlines.

Similarly to that of the positive video analysis variables, the fluctuation within and between variables was great, whilst not following any trend. Any variable lying outside of the confidence interval for that variable was deemed exceptional, both those of a positive exception and negative exception.

Table 6 highlights within which games the number of instances occurring were more than that of the 95% confidence interval. It is also highlighted as to whether the team performed well in terms of points versus the opposition, as well as other variables such as the location of the match and the final ranking of the opposition in the tournament. Once again however, no visible trend was apparent.

**Table 6:** All of the performance indicators highlighting the matches for which the number of instances were greater than the upper 95% confidence interval for that performance indicator.

Performance Indicator		Match								
		1	2	3	4	5	6	7	8	9
<b>Positive</b>	<b>Panga</b>			Yes						
	<b>Terrorist</b>					Yes				
	<b>Offloads</b>						Yes			
	<b>Double hit</b>	Yes				Yes		Yes		
	<b>Big hit</b>	Yes				Yes				
	<b>Positive Tackle</b>			Yes						
	<b>Attacking ruck</b>			Yes						
	<b>Defensive ruck</b>								Yes	
	<b>Turnover</b>				Yes					
	<b>Tries</b>		Yes							Yes
	<b>Positive carries</b>	Yes	Yes		Yes					
	<b>Linebreaks</b>		Yes							
	<b>Conversions made</b>									Yes
	<b>Lineout won (hooker)</b>		Yes				Yes			Yes
	<b>Lineout won (jumper)</b>		Yes				Yes			Yes
	<b>Lineout steal</b>									
	<b>Effective bridge</b>	Yes		Yes						
	<b>Effective scrum (front row)</b>			Yes						
	<b>Effective kick out</b>	Yes								
	<b>Effective kick</b>				Yes			Yes	Yes	
<b>Kick receipt</b>				Yes			Yes			
<b>Negative</b>	<b>Neutral carries</b>	Yes	Yes			Yes				
	<b>Negative carries</b>	Yes					Yes			
	<b>Ineffective kick</b>	Yes			Yes					
	<b>Kick receipt spilled</b>		Yes				Yes			
	<b>Dropped ball</b>	Yes								
	<b>Lost ball</b>				Yes			Yes		
	<b>Poor pass</b>	Yes						Yes		
	<b>Poor lineout throw</b>	Yes			Yes					
	<b>Poor lineout jump</b>	Yes			Yes					
	<b>Missed tackle</b>					Yes				
	<b>Negative tackle</b>								Yes	
	<b>Ruck hiding</b>	Yes								
	<b>Ineffective ruck</b>			Yes	Yes					
	<b>Conversion missed</b>		Yes				Yes			Yes
	<b>Penalty to opposition</b>	Yes					Yes			Yes
	<b>Penalty cards</b>									
	<b>UCT points</b>	19	29	5	16	26	26	15	21	50
<b>Opposition points</b>	52	22	5	24	42	29	37	21	40	
<b>Location</b>	away	away	home	away	home	away	home	away	home	
<b>Opposition ranking</b>	N/A	N/A	4	2	3	5	1	6	8	

## Discussion

The Varsity Cup tournament is unique because of the combination of the level of play (university level), duration of tournament (seven matches in eight weeks), and it takes place in summer (high temperatures). Whilst the tournament is defined as an amateur competition, the teams are expected to perform at a professional level. Also many of the players are students and have the additional burden of studying during the tournament. Therefore this tournament poses unusual challenges and demands on the players and the questions arising from the management of the players are different to other tournaments. In accordance, the aims of the study were to investigate the tools used to monitor and predict changes in training status and determine the effectiveness of these tools to measure the subjective nature of coaches and their selection relating to the players' performance. Another aim was to use performance indicators from video analysis to determine how well these correlated to team performance. The following discussion will address these questions in the context of the data and previously published literature.

### *Session Load*

There was a significant difference between the pre-pre-season session load when compared to pre-season and competition season. The pre-pre-season was performed during the months of November and December (summer in the Southern Hemisphere). It should be noted that there was a three week break between the pre-pre-season and pre-season when the players had their Christmas break, where no formal practices were imposed, however generic training programmes were prescribed to each player. This break was not ideal but has to be considered in the context of all the players being university students living around the country. The university was closed during this period. This long break should be taken into account when comparing the session load for each phase of the tournament. The pre-pre-season load was significantly higher than the other two phases of the tournament. This concurs with previous literature which has examined the loads placed upon players during the different phases of competition<sup>(86,87,88)</sup>. The session load of the pre-pre-season averaged  $1051 \pm 257$  (arbitrary units) per session, where there were three sessions per week. This is similar to the training load per session shown by Killen *et al.* in a group of professional rugby league players who averaged 2809 units per week (i.e.

approximately 936 units a practice)<sup>(87)</sup>. The competitive season training load (583 ± 163 units per session) is in accordance with the guidelines of the National Strength and Conditioning Association (NSCA)<sup>(86)</sup>, illustrating that both the pre-pre-season and competitive season training loads are similar to those imposed on professional players. It is important that the load during the competition phase is lower than during the pre-pre-season and pre-season so that players have sufficient time to recover to perform in the following match<sup>(86)</sup>; during pre-season this is not a concern. However, during the pre-season there is an increased risk of injury due to the higher session loads<sup>(87)</sup>. Gabbett found in a group of rugby league players that when the training load during pre-season training was reduced, so did the injury rates without compromising the physical fitness benefits of pre-season training<sup>(89)</sup>. However, a study performed after this showed there was no relationship between training loads and injury rates in pre-season training.<sup>(87)</sup> This study<sup>(87)</sup> however only used data from one season, whereas Gabbett's study<sup>(89)</sup> used data from three seasons and three changes in training load (there were no changes between the second and third training loads and injury incidence indicating a plateau). This study design enabled the researchers to show a significant relationship between a high training load and high incidence of injury. The adverse effect of injuries within a team preparing for a tournament is important to note and should be carefully considered when the training program is planned.

### *Heart Rate Recovery*

Heart rate recovery, a marker of the regulation of the autonomic nervous system<sup>(90)</sup> has been shown to reflect changes in the training status<sup>(91,92,93)</sup>. According to these findings, a decrease in heart rate recovery (i.e. fewer beats in the first minute after the end of exercise) indicates an inability to adapt to the training stress imposed on the subject, and forewarns against chronic fatigue<sup>(93)</sup>. We hypothesized that the heart rate recovery of the Varsity Cup rugby players would show changes within the pre-pre-season, and all through to the competitive season, reflecting changes in training load and competitive stress. However, there was no significant change in the players' heart rate recovery throughout the season. This suggests the training status/physiological stress of the players remained constant throughout the season and was not affected by the training load or competitive stress. This could be a consequence of the players being well managed on a day-to-day basis, with adequate rest between training sessions, or it may be

concluded the training load was not sufficiently high to induce states of overreaching. The squad was large at the beginning of the pre-pre-season, but from pre-season the squad became much smaller and thus much easier to manage, adding credence to the interpretation that the players were well managed. An alternative interpretation is that the duration from the beginning of pre-pre-season to the end of the tournament was eighteen weeks (with a three week break), and thus could possibly be too short for players to incur and show symptoms of physiological overreaching or overtraining<sup>(94,16)</sup>. As seen in Figure 3, there was no correlation between the changes in session load and heart rate recovery, reinforcing the conclusion that the physiological stress of the training load was adequately compensated for by the players' recovery. However, it must be noted that using only heart rate recovery as a measure of overreaching or overtraining is not infallible.

### *Physiological Testing*

The battery of tests performed at the beginning of the pre-pre-season and pre-season phases of the season to measure physical characteristics and performance showed that the forwards were significantly heavier than the backline players, as observed by many other researchers<sup>(2,95,49,47)</sup>. The forwards were also taller than the backs (as previously shown)<sup>(54,2,49)</sup> and had a higher body fat percentage.<sup>(2)</sup> There was no significant increase in body mass, between the pre-pre-season testing and the pre-season test. This was unexpected, and could be a cause of the players not following their programmes during the break, or that the programmes prescribed were not intended for a hypertrophy phase (as is typical during the pre-pre-season/pre-season phase)<sup>(87)</sup>.

The forwards were stronger, as measured by the bench press, were slower over 10 m and 40 m and reached a lower level in the Yo-Yo test when compared to backs; these results were in accordance with previous research<sup>(58,50,66,65)</sup>. There were, however, significant increases in speed over 40 m and in the Yo-Yo test between the pre-pre-season and pre-season testing in forwards and backs. This indicates the pre-season training programme did increase the speed and athletic endurance of the players<sup>(88)</sup>. The forwards got stronger over the pre-pre season to pre season period, in contrast to the backs who did not. This is possibly a consequence of the different training the positional groups were performing during this time, which caused the players to

adapt differently. The forwards performed more static drills such as line-outs and scrums, whereas the backs performed more dynamic attacking drills, such as running their lines and various designed “moves” to increase their chances of scoring tries. Whilst the model of prescribing programmes, which are position specific is best practice, it should be noted that all players regardless of position should ideally become stronger (with the forwards still having a strength advantage over the backs but with both groups having a similar improvement) <sup>(57)</sup>.

There were multiple significant correlations between the various tests. For example, body mass was related to stature, body fat percentage, a decrease in speed, pull-ups and endurance ability. All of these relationships are common knowledge and expected in the general population<sup>(56)</sup>, however in the professional athlete population these trends do differ. In the rugby population, this trend agrees with previous literature owing to the physical nature of the game<sup>(2)</sup>; but in other sports, such as track events, this may be different. Many of the correlations followed the same trend (e.g. body fat percentage and the correlations to stature, speed, pull-ups and aerobic fitness).

Interestingly, as the number of pull-ups increased, and by implication local muscular endurance, so did the players’ speed (40 m) and aerobic fitness. It may be argued that the decrease in body fat percentage, which correlated with the increase in pull-ups, speed and aerobic fitness, contributes to this ability to perform better in these physical tests. However, it is not that simple because when the aerobic fitness increased, the speed decreased. The observation that an increase in pull-ups correlates with both increases in aerobic fitness and speed, is interesting and warrants further investigation because it has implications for the physical preparation of the players.

Specificity of training is an important aspect to consider when prescribing training, particularly in a sport such as rugby which has diversity both in the physical characteristics of the players and in the position-specific demands of the game. It is important to avoid this paradox of aerobic fitness increasing, while speed decreases, especially in rugby union where the ability to perform short sprints is an important aspect of performance.

Since pull-ups were correlated to many of the other physiological tests, monitoring pull-ups could be potentially important, because when the player's number of pull-ups increased, all these other performance indicators moved in the ideal direction. The second testing battery performed at the beginning of the pre-season phase, was immediately after the three week Christmas break. This break was the period when players performed their own training and were unsupervised, possibly resulting in erratic training. When looking at relative changes (Table 5), there were fewer significant correlations. In summary, there were many changes in physical attributes, however not all went in the coaches' intended direction. The coach would have hoped for an increase in all aspects (body mass is debatable depending on their lean body mass versus fat ratio), except in the body fat percentage and sum of skinfolds, where they would have aimed for a decrease.

### *Body Mass Variation*

The body mass of rugby union players is often measured to identify which players are/are not adapting to the rigours of practice and matches, particularly when the conditions are hot<sup>(1)</sup>. Training regularly may cause a progressive decrease in body mass if the player fails to match the loss of body water with increased fluid intake<sup>(96)</sup>. Body mass is an easily measured variable which provides immediate and meaningful feedback to the player.

The body mass was always recorded at the beginning of practice to eliminate the acute effect of the practice. The body mass of the players fluctuated over the course of the season (pre-pre-season to end of competition), which is regarded as normal, however there were certain players who's fluctuation exceeded normal (Figure 4). There was no significant difference in the coefficient of variance between the forwards and backs, indicating that the different physical demands of the positions was not the reason for certain players having a much larger variation compared to the other players. The larger variation in body mass was also not related to body size. When the players with a larger variation were examined in more detail there were no other indicators which identified them as having incurred any other maladaptations. The large variation could be explained by the hydration habits of the players. Certain players prefer to drink copious amounts of water/fluids throughout the day, which could lead to changes in body

mass<sup>(1)</sup>. During pre-pre-season and pre-season the team practiced on Monday, Wednesday, Thursday and Saturday. Certain players may have failed to match the fluid loss during practices during the off days causing a progressive decrease in body mass during the week<sup>(96)</sup>. Fluid retention and replacement is a common cause of body mass fluctuation, and it is important to maintain the correct balance to optimize performance and health status<sup>(97)</sup>. The appropriate hydration of players, and concern over players becoming dehydrated, is a major driving force for the weighing of players with the goal of avoiding this becoming a health concern for the players. This, however, is hypothetical, because our data showed there were no differences between the players whose body mass fluctuated greatly, and those who did not. However, different conclusions may have been reached had the season been longer.

### *Playing Time and Physical Tests*

Although previous studies have shown a correlation between the performance of players in the battery of tests and selection for matches<sup>(25,23,51)</sup> the evidence regarding selection and physiological testing is conflicting. The lack of correlation between selection and stature, body mass and speed all agree with previous literature<sup>(25,23)</sup>. Speed was a significant predictor of starting or not starting a match in professional rugby league, but in junior rugby league it was not significant, leaving it inconclusive<sup>(25,23)</sup>. Body mass is similarly inconclusive, as in one study body mass was a predictor of the number of minutes played in rugby league<sup>(51)</sup>, whilst in another study it was not significant when starters and non-starters were compared<sup>(23)</sup>. In this study there was no correlation between the usual variables noted to be associated with selection (e.g. body mass, stature, body fat percentage, strength, muscular endurance, speed and endurance), and the number of minutes played by the players in the squad during the tournament. Although we used the number of minutes played by each player as a measure of selection, we acknowledge there may have been pitfalls in this method because the sample was relatively small, it was a homogenous sample of players and that players who got injured (and could therefore not be available for selection for a match) were not accounted for. It is also important to note that possibly the data is population specific rather than inconclusive.

## ***Coaches Ratings***

Studies have looked at the selection of players by coaches, with predictors such as their previous match performance being a significant predictor<sup>(72)</sup>. Our study on the other hand looked at predictors during practice and the differences between coaches, and how this affected selection.

When looking at only practices, there was a significant difference overall between the “effort” scores of Coach 2 when compared to both the other two coaches. Coach 2’s “effort” ratings were significantly higher than the other two coaches; this could be due to the coach being the only coach among the three who was a previous player in the team. Therefore he would have had insight into how hard the players were trying and perhaps been more empathetic to their efforts and as a result scored “effort” higher than the other coaches.

When looking at the ratings of the players selected and those not selected for the week preceding the match, there were only a few differences between the two groups. Coach 1 and 3 had significant differences in one match each for “accuracy” (not the same match), for “effort” there were no differences and for “focus” Coach 1 had two matches in which the scores for players selected vs. players not selected were different. As there was no pattern for these significant differences, it can be interpreted that there was no correlation between player performance in training and their selection for the match at the end of the week. This agrees with Trinic *et al.* (1999) who proved there was no impact on selection from their performance in training (elite basketball players), and merely their previous match performance<sup>(72)</sup>. It could also be attributed to having a relatively small squad of players with homogenous characteristics, where practice performance is not enough to determine selection. Another factor that could distort this data could be the nature of injuries causing them to be unavailable for selection. In this case their practice performance was irrelevant if they were not match-fit yet. Another factor could be that with the size of the squad the coach could rotate the players according to a predetermined plan, which was independent of how they performed in practice.

The ratings of the head coach (coach 3) of the selected players the week preceding a match and his ratings of them for their match performance showed significant differences in one match for “effort” and “accuracy”, and in three matches for “focus”. Once again there was no pattern in the

results. Furthermore, once a correlation between the pre- and post-match ratings was performed there was a significant correlation for all three factors (“focus”, “effort” and “accuracy”), albeit with low predictability (9% to 22%). This illustrates that the player’s performance in practice in the week before a match accounts for a relatively small amount of how they perform in the match. This is not unexpected. One study looked at the coaches’ perspectives, where it was illustrated that the players (professional rugby union players) do not always implement the training when in a match situation. This finding supports the results of Coach 3 in this study<sup>(98)</sup>. It must be noted that this performance is merely a subjective rating on those three indicators, but other factors could contribute to the ratings given by the coach. Another factor to consider is that the team lost six out of the seven matches played in the Varsity Cup tournament. It would be interesting to repeat the study during a season when the team has a more varied set of results, including more wins. Also the match ratings vs. practice ratings should also be performed by the other two coaches to see the difference in interpretation of the players during a match.

How the coaches interact is important and may impact on the overall performance of the team. A study has examined the interplay between the coaches in a rugby union team, and how this added stress to the head coach (in our study Coach 3) when it came to selection and views on strategies for matches<sup>(98)</sup>. The fact there were scoring differences among the coaches in this study suggests that this is an area that needs attention to reduce the potential stress of the head coach.

### *Video Analysis*

Video analysis in many sports has become imperative in game analysis and assisting coaches to determine the weaknesses and necessities for future matches<sup>(77,99,3,79)</sup>. The video analysis data from this study did not show any visible trends in the performance indicators (both positive and negative variables). There was large variation within each variable, and when compared to match score or outcome there was no visible association. This could be due to the team having drawn two, won one and lost the rest of the matches for the tournament and therefore making the discrimination between results very difficult to determine. Previous literature has shown how performance indicators such as passes made, rucks won and turnovers, can predict a win or loss, so there is evidence to support the importance of these variables and the ability to implement

them<sup>(79)</sup>. The lack of correlation in our study should mostly be attributed to the lack of change in performance.

Once again, the video analysis data should be performed again, but on a team in the Varsity Cup tournament which performs differently to the team reported in our study and has a more varied match outcome.

### *Limitations*

The study was conducted on a team who performed poorly in the tournament, and should be repeated on a more successful team to get a better understanding of the tournament and its effects.

## Summary and Conclusions

In summary, monitoring players during the Varsity Cup tournament is a complicated task for coaches, and opens itself up for much research into optimizing performance at this level. With the tournament starting in 2008 and therefore being relatively new, there is little research on the demands on the players for this level of rugby<sup>(46)</sup>, making this study novel.

The session load matches the guidelines put forward by the NSCA and other research<sup>(87,86,100)</sup>, and along with the constant heart rate recovery data through the season, suggests that the balance between training load and recovery was appropriate and did not cause any maladaptations or symptoms of overtraining. This suggests the players were well managed.

The study has shown much agreement with previous literature regarding the anthropometric and physiological characteristics of rugby union players across the age groups and playing level<sup>(2,50,60,58)</sup>. However, unlike in previous literature, there was no correlation between the players' ability to perform in the physiological testing battery (anthropometric measures included) and the selection of players<sup>(25,71)</sup>. This contradicts previous literature, but can be explained by the player population in this study which was pre-selected and fairly small. The body mass of the players' fluctuated, with the extent of the fluctuation not being dependent on the positional group or on the player's body mass. The fluctuation of body mass also had no apparent influence on playing performance, indicating the fluctuation is just the body's normal response to daily activities and training.

The novel section of this study is the coaching data. Understanding the coaches' interpretation of player performances and attitudes is intricate and could potentially contribute to better understanding of player selection. The study found that the interpretation of the players' "effort" at practice between coaches (all within the same team) differed. However, once the players were analysed based on their selection or non-selection for a match, there were only a few weeks in which there was a significant difference between the selected and the non-selected players. This non-finding clearly indicates that within a small squad of players the difference between being selected or not-selected, is so insignificant that the players do not differ much in their perceived

“performance” at practice. When analysing the data of the head coach alone, there was a correlation between the pre-match practice ratings and the players’ match ratings. Although the predictability was low, the correlation could serve to indicate that the perceived “performance” during the pre-match practices could predict how the player would perform in the upcoming match. The coaches’ data provides further insight into the coaching aspect of university rugby union and should be further investigated.

The final aspect of the study was the video analysis. The video analysis did not show any significant findings, largely owing to the team performing poorly in all matches and therefore not allowing for much variation in the match results. Video analysis is a key component in professional rugby, and future studies on a Varsity Cup team with varying performances would be important to consider.

In conclusion, Varsity players need to be managed carefully. They may not be professional players according to the classic definition, but the nature of the tournament and the expectations the universities and supporters have of the players suggests they need to be managed as if they were professionals. Physiological testing is important, to ensure the players meet the expected standards, whilst constant physiological monitoring (i.e. heart rate recovery) allows for the players to be flagged if they are not adapting appropriately to the training load. Also the coaches should rate the players constantly; this will increase the pool of knowledge regarding coaches, and it will also help the coaches to engage with quantifying the players “performance” during practices. All these variables contribute to a team being better managed which will increase the chance of the team reaching its full potential.

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## Appendices

### *Appendix 1: RPE Scale*

#### Perceived Hardness of Practice

<b>0</b>	Rest
<b>1</b>	Really Easy
<b>2</b>	Easy
<b>3</b>	Moderate
<b>4</b>	Sort of Hard
<b>5</b>	Hard
<b>6</b>	
<b>7</b>	Really Hard
<b>8</b>	
<b>9</b>	Really, Really Hard
<b>10</b>	Just Like My Hardest Race

Appendix 2: Coaches' Rating Scale

Player	Player Performance Ratings (Scale 1-5)														
	Focus					Effort					Accuracy				
Francois Van Wyk	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Ollie Kebble	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Digby Webb	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Peter Olivier	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Sti Sithole	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Joel Carew	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Shane Meier	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Decan Chowles	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Dayne Jans	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Neil Rautenbach	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Timmy Louw	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Michael Willemse	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Levi Odendaal	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
James Kilroe	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Stephen Burger	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Johno De Klerk	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Shaun Mcdonald	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Brad Bosman	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Ntsolo Setlaba	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Kyle Kriel	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Rayn Smid	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Josh Katzen	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Mike Botha	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Jason Klaasen	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Steve Wallace	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Dylan Frylink	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Ricky Shroeder	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Liam Slatem	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Nick Holton	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Ross Jones Davies	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Tiger Bax	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Andrew Norton	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
David Abunya	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

SCALE				
1-Poor	2-Below Average	3-Average	4-Above Average	5-Good

	Day
	Date
	Coach Name
	Session Duration

Darren Berry	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Robbie Louw	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Kyle Lombard	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Nico Loizedes	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Richard Stewart	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Nathan Nel	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Paul Cohen	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Dillyn Leyds	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Dylan Sage	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Selom Gavor	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Jason Germishuys	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

*Appendix 3: Informed Consent*



Informed consent for UCT rugby testing 2011

This letter serves to obtain permission from you the player to use any data collected during testing for future research.

I understand that by signing this form I give permission for the data collected from me during testing can be used for the purpose of research.

I understand that the data collected will be kept confidential at all times.

I have been informed that of the tests that will be conducted and have had an opportunity to ask any questions.

Signed: \_\_\_\_\_ (participant) \_\_\_\_\_ (date)

\_\_\_\_\_ (investigator)

\_\_\_\_\_ (witness)