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DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT AND PHYSICAL EDUCATION

A TIME-MOTION ANALYSIS OF AMATEUR RUGBY LEAGUE WITH SPECIAL REFERENCE TO REPEATED HIGH-INTENSITY EXERCISE

RHYS PRITCHARD

09001618

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Abstract

The study aimed to investigate the physiological demands of amateur rugby league forwards and backs, through the application of time-motion analysis. Observation of ten games (n=10) was verbally coded, regarding the on-field activity of five forward (n=5) and five back positions (n=5) and upon play back was coded into a computerised system regarding the seven locomotive movement classifications. On one occasion, video recording of one position allowed a reliability assessment to be carried out. Repeated playback of playercam video footage was manually coded into a computerised match analysis system Studiocode. An intra-observer (κ=0.83) and inter-observer reliability (κ=0.81) study, failed to reveal any significant differences in the duration spent in each locomotive classification, reporting a very high strength of agreement. Ten players completed one 40m time-trial using electronic timing gates, in each locomotive movement to calculate velocity profiles, and estimate distances (Smartspeed Fusionsport, Australia). The mean total distance for amateur rugby players was 6540.6 ± 1003.9m, with backs (6989.4 ± 924.2m) travelling significantly greater distances than forwards (6091.7 ± 953.9m). Backs also had significantly lower work to rest ratios (1:11) than forwards (1:6), on which highlights the high-intensive intermittent nature of the game. Additionally, the repeated high-intensity exercise bouts of forwards (9.4 ± 3.8) and backs (9.6 ± 3.5) further highlights the most demanding periods of the game, changing activity on average every 5.5s. Consequently, the intermittent nature reported within the present study has an influence upon the provision of positional specific training programmes to amateur rugby league players.

CHAPTER I

INTRODUCTION

1.1. General Background to the Study

The physically demanding contact sport of rugby league is played at progressive hierarchical levels from amateur to professional (Brewer and Davis, 1995; Gabbett, 2000a). A rugby league team is composed of 13 players, competing to gain territorial advantage of the opposition by carrying, passing, kicking and grounding the ball, to score points over two periods of 40minutes (min) (Gabbett, 2008a). A team is classified into two playing groups of forwards (i.e. involved in scrum) and backs (i.e. not involved in scrum) that compete to maintain possession through the exertion of pressure, continuity, support and invading the territory of the opposition in an attempt to score points (Biscombe and Drewett, 1998) (Figure 1).

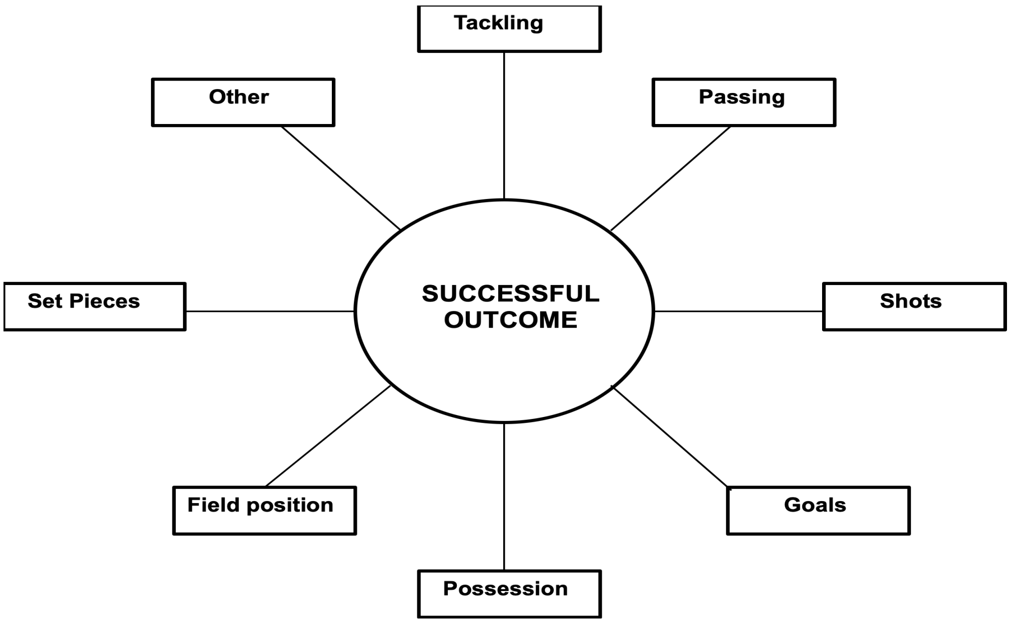

Figure 1: Contributing factors to success in invasive games (adapted from Hughes and Franks, 2004).

Understanding the physiological demands of rugby league can assist coaches and players through the decision making process and is an accessory to the development of a specific conditioning programme (Gasston and Simpson, 2004; O'Donoghue, 2006). The educational tool of performance analysis can provide empirical evidence regarding technical analysis, tactical analysis, movement analysis and performance profiling (Hughes and Franks, 2004). When the training stimulus imitates the competitive conditions, physiological adaptations are advantageously developed (Deutsch *et al*., 1998; Davidson and Trewartha, 2008).

Initial methods of time-motion analysis involved the application of circuitous hand notation systems (Reilly and Thomas, 1976). Time-motion analysis (TMA) is a gold-standard observational method, used to objectively quantify and report the physiological and technological demands of field sports (Bangsbo, 1994; Duthie *et al*., 2005). The application of TMA has provided information regarding the movement demands of Rugby Union (Docherty *et al*., 1988; Duthie *et al*., 2005) Netball (Otago, 1983; Steele and Chad, 1992; Davidson and Trewartha, 2008) Hockey (Spencer *et al*., 2004; Spencer *et al*., 2005) and rugby league (Meir *et al*., 1993; Meir *et al*., 2001a; Sirotic *et al*., 2005; King *et al*., 2009). There is however, limited information regarding the movement profiles of contemporary amateur rugby league forward and back positional groups (Gabbett *et al*., 2008a).

1.2. Rationale of the Study

Research of rugby league at semi-professional and professional standards, hypothesised an improvement in physiological capability and skill abilities as the level of competition improved (Gabbett *et al*., 2007a; Gabbett *et al*., 2007c; Gabbett *et al*., 2009). The elevated physicality of professional rugby league players can enhance the intensity of which the game is played and further, the demands of competition when in comparison to amateur rugby league (Gabbett, 2008a). Physiological demands of rugby league at varied levels are not comparable, therefore an investigation into the demands of amateur team is warranted (Gabbett, 2008a).

The skill ability, as well as morphological and physiological endowment, determines the positional roles a player will fulfill (Gabbett, 2000a). Positions in rugby league have contrasting match activities and therefore require specific conditioning programmes (Gabbett, 2000a; Gabbett, 2005b; Gabbett, 2008a). Although activities in amateur rugby league are specific to the position, the physiological conditioning and training routines are demonstrated to be uniform for all positions (Gabbett, 2000a). The quantification of match demands within forwards and backs would provide empirical evidence in order to administer a specific conditioning programme (Gabbett, 2008a).

Modification of legislations has enhanced the demands of contemporary rugby league. Quantification of the demands within professional rugby league have witnessed elevated displacement in forward and back positions, following amendments to defensive and interchange laws (Meir *et al*., 2001). Amateur rugby league has not undergone such scientific research under the current legislations and therefore demands of amateur rugby league, have not been empirically supported (Gabbett, 2008a). The limited research into the quantification of the physiological demands, fails to facilitate the provision of scientific support to an organisation of a novice level. Research at a professional level, amendments to legislations and interest into contrasting positional groups; have influenced exploration into the demands of amateur rugby league.

1.3. Aims of the Study

The purpose of this study was to quantify physiological demands of amateur rugby league, through the application of specified movement classifications. In addition, to identify the prevalence of high-intensity repeated sprint activity and repeated high-intensity exercise in forward and backs positional groups, reporting the intermittent nature of amateur rugby league. Overall, the study will supply a synopsis into the demands of amateur rugby league forwards and backs and provide support in the development of practical conditioning programmes.

1.4. Hypothesis

The following hypothesis were generated and tested through the application of time-motion analysis in amateur rugby league.

- H_0 No significant differences will exist in; the frequency, duration, distribution, and distance covered in the selected locomotive classifications, or that concerned with high-intensity activity between forwards and backs or first and second half periods.
- H_1 Significant differences will exist between forwards and backs in the frequency, duration, distribution and distance allocated to selected locomotive classifications.

- H_2 Significant differences will exist between forwards and backs in the frequency, duration, distribution and distance allocated to high-intensity activity.
- H_3 Significant differences will exist between forwards and backs for the mean work-to-rest ratio and repeated sprint activity.

1.5. Scope

The selected populations used as a sample were limited to amateur rugby league players who compete in the Co-Operative Welsh Conference.

1.6. Limitations to the Study

Individual, environmental and oppositional factors could not be controlled due to the ecological validity associated with performance analysis and observational assessment (Steele and Chad, 1992). Therefore, the work-rate of players throughout different positions and games could potentially be influenced by external factors.

Progression through the rugby league season has been associated with reductions in muscular power and VO_{2max}, while injury rates were higher and training loads were decreased (Gabbett, 2005c). With the study occurring throughout the competitive season work-rate may be influenced negatively during the latter stages of the season.

1.7. Delimitations of the Study

Limited competitive fixtures throughout the season resulted in a small data collection of ten data sets. The limited sample size may infer the probability of type one or type two error when generalising to a population.

The methods used to calculate the distance travelled had limitations. The quantification of distance was calculated by velocity profiles and the assumption that the velocity was constant in each locomotive movement classification throughout the game.

1.8. Definitions of the Terms

- Work-to-rest ratio (W:R) – The duration spent in low-intensity activity in correlation to the duration spent in high-intensity activity.

- Repeated sprint activity (RSA) – A minimum of three sprints with <21 seconds recovery (Spencer *et al*., 2002).
- Repeated high-intensity activity (RHIE) – A minimum of three sprints, rugby related activity or shuffling locomotion with <21 seconds recovery (Spencer *et al*., 2002; Austin *et al*., 2011).

CHAPTER II

LITERATURE REVIEW

2.1. Action Research

The development of sport throughout the 20th Century has encouraged action research to obtain empirical evidence and reinforce decisions made in a coaching context (O'Donoghue, 2010). Analysis of sport, regarding the proficiency of performance can be used to supplement the acquisition process of athletic development (Hughes and franks, 2004). Consultants of sport and exercise science can observe, measure and record indicators of performance to provide data of statistical significance (Hughes and Franks, 1997). The developments within sport science and the discipline of performance analysis are far exceeding the subjective and interpretive paradigms of coaching interventions (O'Donoghue, 2010). Successful performance and skill acquisition is determined on the accuracy and objectivity of augmented feedback (Franks, 1996; Franks, 2004). Furthermore, the inconsistencies involved with coach recall has encouraged objective measures of performance, through the application of computer-aided analysis (Launder and Pitz, 2000; Hughes and Franks, 2004).

Performance analysis can be utilised to assist and support in planning and implementing improvements through the coaching model, to provide accurate and valid augmented feedback relevant to performance objectives (Hughes and Franks, 2004) (Figure 2). The effectiveness of performance analysis in a coaching context has been criticised for its influence upon coaching and tactical decisions (Hayes, 1997). It has however been hypothesised, instructional feedback, self-talk and self-modeling can improve technical ability and performance. This therefore provides a rationale for utilising performance analysis in an applied coaching context (Franks, 1997; Theoderakis, 2000).

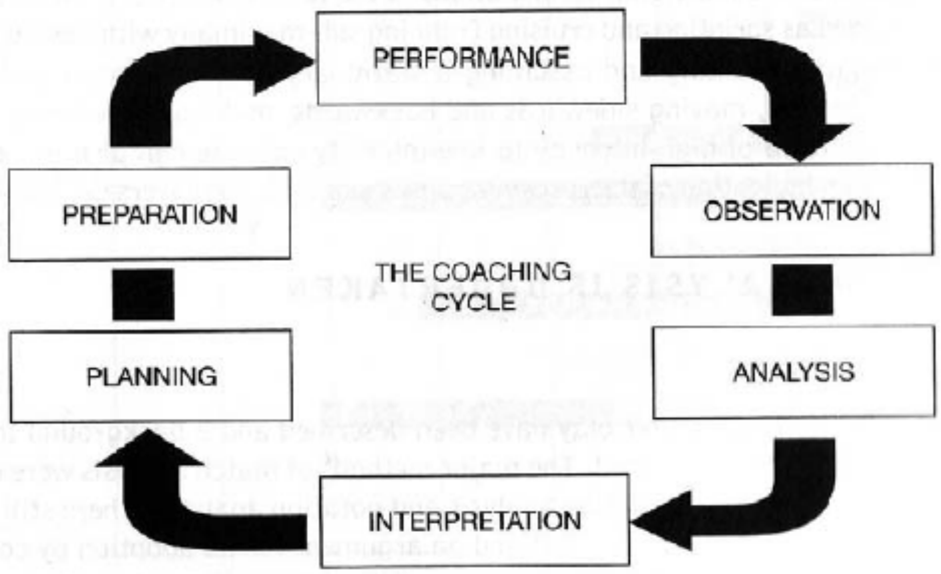

Figure 2: The coaching process. (Carling *et al*., 2005).

Rugby league, and other comparable field-based sports, is not limited to one unique energy pathway to sustain the metabolic demands experienced throughout the game (Docherty *et al.,* 2003). The games short recovery periods, interspersed with frequent and intense activity, is the catalyst for the utilisation of all three energy systems (Gabbett, 2000a). The integration of the creatine-phosphate, glycolysis and aerobic energy components is determined by the demands of the exercise (Gastin, 2001). Understanding the demands of a sport can provide sufficient evidence to prepare and technically improve performance (Gabbett, 2008a).

In the high intensive collision sport of rugby league, it is not uncommon for players to have well developed aerobic power, speed, agility, muscular strength and muscular power (Gabbett *et al*., 2008a). It is good practice for the coach to implement training programmes that fabricate the patterns of movement and physiological demands of competition (Thompson *et al.,* 2007). Rushall and Pyke (1990) argue, failure to provide specific strength and conditioning programmes can inhibit the training developments made by the athlete. Developing knowledge and understanding of the movement patterns will not only optimise training, but allow valid and reliable fitness assessment regime to assess the athlete’s current state of fitness. Gabbett (2006) theorised that the application of skill-based conditioning games offer alternative methods for in-season training methods, rather than traditional and instructional conditioning programmes. This is attributed to the simulation of movement patterns under oppositional pressure in a safe environment, whilst maintaining intensity under the effects of fatigue (Gabbett *et al.,* 2010). Additionally, providing an opportunity to practice rugby league skills that are shown to be poorly developed in amateur rugby league (Gabbett, 2000a). This therefore demonstrates a value for practice to be specific and imitate the technical and physiological demands of competition.

2.2. Intensity, Fatigue and Injury

It has been demonstrated and hypothesised by Gabbett (2008b), performing in a state of fatigue is the catalyst for a decrement in tackling proficiency. Several studies have hypothesised a correlation in changes of intensity, duration and load with increased injury rates in professional (Gibbs, 1993; Seward *et al*., 1993; Estell *et al*., 1995; Gissane *et al*., 1997; Gabbett, 2004a), semi-professional (Gabbett, 2011) and amateur rugby league (Gabbett, 1999; Gabbett, 2000). The incidence of injury is diagnosed to escalate at contrasting playing levels, during second half periods, pre-season and latter stages of the season (Gissane *et al*., 1993; Gabbett, 2000a). Intensity, skill level and physical conditioning of the player are believed to influence injury rates and severity of the injury (Stephenson *et al*., 1996; Gabbett, 2001; Gabbett, 2011).

Understanding the incidence of injury and the effect of fatigue can help to manipulate strength and conditioning programmes to develop cardio-respiratory fitness, agility and tackling technique when fatigued (Gabbett, 2001a). This was thought to minimise the injury frequency, health and financial injury costs of amateur rugby league players (Gabbett, 2000).

2.3. Time-Motion Analysis

The concept of notating movement incidences throughout a match can be used to document the fitness requirements of a sport (Hughes and Franks, 1997). One current method within performance analysis research is concerned with the duration and distance allocated to individually selected locomotive movements within field sports, more commonly referred to as time-motion analysis (TMA)

(Spencer *et al.*, 2005; Austin *et al.*, 2011). As a result of such research, physiological demands of sport, injury incidence and tactical information can be documented (O'Donoghue, 2008). These variables can be a determining factor when designing a conditioning program to ensure its functionality and avoid anecdotal evidence within the field (Thompson *et al.*, 2004).

Considering the intermittent nature of field sports and the effectiveness of empirical evidence and valid augmented feedback on performance, it is understandable for the substantial research into the physical demands and high-intensity activity of sports such as soccer (Reilly and Thomas*,* 1976; Withers *et al.,* 1982; Mayhew and Wenger*,* 1985; Yamanaka *et al*., 1988; Bangsbo *et al*., 1991; O'Donoghue and Parker, 2002; Mohr *et al*., 2003; Castellano *et al*., 2011) hockey (Lothian *et al*., 1994; Spencer *et al*., 2004; Spencer *et al*., 2005; Macleod *et al.,* 2007) counterpart game of rugby union (Docherty *et al*., 1988; Duthie *et al.,* 2005; Roberts *et al*., 2005; Deutsch *et al*., 2007) and rugby league (Meir *et al*., 1993; Estell *et al*., 1996; Meir *et al*., 2001a; Coutts *et al*., 2003; Beck and O'Donoghue, 2004., Sirotic *et al*., 2005; King *et al.*, 2009; Sykes *et al.,* 2009*;* Sirotic *et al*., 2009; Austin *et al*., 2011; McLellan *et al*., 2011). Although the literature of work-rate within sport is increasing, there is a paucity of TMA studies within amateur rugby league. With limited research in this area, it is not possible to simulate the demands of amateur rugby league within strength and conditioning programmes, or simulate the demands as part of a fitness assessment (Spencer *et al.,* 2004; King *et al.*, 2009; Sirotic *et al.,* 2009).

2.4. Playing Level

Research into the physiological characteristics of sporting athletes has discovered popular trends between elite and amateur competitors. It is not unlikely for elite athletes to exceed amateur physiological and technical ability with elevated speed, power and cardio-respiratory fitness (Rigg and Reilly, 1987; Montgomery *et al.*, 2006; Gabbett *et al*., 2007a; Gabbett *et al*., 2009). Specific to rugby league, Sirotic *et al. (*2009) reported the variation in physiological characteristics between amateur, semi-elite and elite rugby league athletes in body fat percentage (18.7 ± 1.7%, 16.4 ± 1.7%, 13.9 ± 1.8%), maximal volume of oxygen (38.9 ± 3.6, 50.0 ± 2.5, 62.6 ± 5.4 ml/Kg/min), speed over 10 meters (m) (2.58, 2.17, 1.17seconds [s]) and speed over 40m (6.63s, 6.04s, 5.08s) respectively (Larder, 1992; Gabbett, 2000; Meir *et al*., 2001b; Gabbett, 2002). Elite athletes also excel in ball carrying ability, passing, contact and evasion skills when fatigued (Gabbett *et al.,* 2007c). The skill ability of rugby league players is the distinctive characteristics that separate athletes of elite and amateur playing levels. Physiological and anthropometric characteristics are not essential determinants of competent rugby league players, but are related to player ability (Gabbett *et al.,* 2007c). Inhibited levels of physical fitness in amateur rugby league can be attributed to sporadic participation of competition, non-intensive game play and 30-53% decreased training and conditioning than elite players (Gabbett, 2000).

The advanced physicality and fitness ability of elite rugby league players enhances the intensity, injuries and physiological demands of competition. It has been initially documented by Meir *et al.* (2001a) that elite rugby league forwards and backs cover greater distances (~9929 and ~8458m) than semi-elite (~8500 and ~8000m) and higher-intensity running during first half and entire game (Sirotic *et al.,* 2005). Several studies have enumerated the demands of semi-elite and elite rugby league, however many were conducted prior to the implementation of the 10m legislation (1994) and during the limited interchange rule (2008) (Meir *et al*., 1993; Meir *et al*., 2001a; Coutts *et al*., 2003; Estell *et al*., 1996). The recent interchange law has not been implemented into amateur rugby league as it is thought to negatively affect the intensity, increase fatigue and reduce accuracy of amateur rugby league players. Current reviews have hypothesised that the amateur rugby league players have diminished fitness and technical ability resulting in greater duration spent in low-intensity activity (LIA), under the contemporary rugby league rules (Gabbett, 2008a). It is therefore important to highlight any previous TMA research of professional rugby league, can not be applied to an amateur level due to the contrasting match play and physiological and technical ability.

2.5. Ten Meter Rule Change

Systematic assessment of the methods used in performance analysis is not uncommon, as objective information can be applied to the field of sport. The reliability of results may be consistent at the time, but the ability to generalise to a population, proceeding the era the study was conducted has complications (O'Donoghue, 2010). Potential developments in sport, technology, training practice and rule changes can indirectly affect the physiological demands of sport. A sequel study by Meir *et al.* (2001a) quantified the ramifications of the 10m legislation on physiological demands of professional rugby league. The legislation requires the defensive system to retire by 10m after a tackle completion from the play of the ball or to their goal line, double the previous 5m requirement (National Rugby League, 2002). The amplification of defensive distance is thought to provide additional challenges to the defensive structure in amateur rugby league, enhancing errors in contact and further injury (Gabbett, 2008b). However, the impact of the 10m defensive legislation has not been quantified in amateur rugby league.

Initial research into the demands of rugby league was conducted by Meir *et al.* (1993) comparing the requirements of forward and back positions. It was reported that distances ranged from 6530m and 7921m, further hypothesised to increase under the 10m legislation to an estimated of 9929m and 8458m respectively (Meir *et al.,* 2001a). The increased displacement between defensive and offensive structures provides greater demand for players to retreat before the next play of the ball in order to be "onside" and participate in game play (Rugby Football League, 2002). This is thought to be the catalyst for an increase in high-intensity unrewarded activity in forwards jogging (7.5%) and low-intensity unrewarded walking (10.4%) in backs under the 10m legislation (Meir *et al*., 2001). Moreover, with increased distances and high-intensity activity of forwards, an expected increase has been witnessed in work (ATP resynthesis) to recovery (PCR resynthesis) ratios from 1:6 and 1:8 under the 5m legislation to 1:7-1:10 and 1:12-1:28 under 10m legislation for forwards and backs respectively (Meir *et al.,* 1993; Meir *et al*., 2001). The excelled recovery periods and total distance are thought to increase aerobic metabolism, potentially changing the physiological demands of rugby league (Gabbett *et al*., 2008b). Information regarding the effect of the 10m legislation upon amateur rugby league is required to enhance the specificity of conditioning programmes (Gabbett *et al.,* 2008a). The dated studies by Meir *et al.* (2001a) have been criticised for its small data set recording only four playing positions, and consequently pre-dated the limited interchange legislation (Sykes *et* *al*., 2009).

2.6. Unlimited Interchange Law

Initial legislations in rugby league permitted teams to interchange players as frequent as required, with the rationale to prevent blood-borne diseases and to dismiss allegations of beneficial replacement of players with head injuries (Clearly, 2011). Amendments to the legislation initially reduced the replacements to twelve (2001) and further reduced to ten (2008) in elite and semi-elite rugby league (National Rugby League, 2002). Moreover, amateur rugby league players are permitted to interchange players as frequently as required (National Rugby League, 2002).

King *et al*. (2009) recorded total distance of professional rugby league players documenting no significant difference in distance travelled by outside backs (6265 ± 318m), adjustable (5908 ± 158m) and hit-up forwards (4310 ± 251m). The displacement of positions is supported in current professional rugby league studies with forwards and backs travelling (4982 ± 1185m) and (5573 ± 1128m) respectively (McLellan *et al*., 2011). The preliminary research discussed by Meir *et al.* (2001) overestimates the displacement of forwards (9929m) and backs (8458m) in professional rugby league. The exaggeration and inconsistency in the calculation of total distance could potentially be attributed to developments within technology, defensive rule changes and amendments to the interchange law (King *et al*., 2008; McLellan *et al*., 2011). Additionally, other than the un-comparable methods, the limited interchange law is the single variable that differentiates the studies, and is therefore evident to influence the physiological demands of contemporary rugby league (Orchard *et al*., 2003).

Competing under the limited interchange law could potentially enhance risks to amateur player welfare obligating players to compete in a fatigued state (Orchard *et al*., 2003). It would not be unexpected if the displacement of amateur rugby league players is exaggerated while competing under the unlimited interchange rule, as there would be increased replacements and intensity in an attempt to maintain skill level (Gabbett, 1999). Elaboration upon the previous research into the physiological demands of elite and sub-elite rugby league under the 10 man interchange rule and demands of amateur rugby league under unlimited interchange rule are warranted.

2.7. Forwards and Backs

The physiological demands of the game are positional specific (Gabbett, 2005a). Additionally the physiological characteristics of forwards in rugby league provide evidence of superior body mass, and inhibited velocity over 40 and 10m sprint, in comparison to backs (Gabbett, 2000). These morphological characteristics are personified to the role of the position during the game play. Gabbett (2005a) proposes that forwards require greater body mass, to contend within physical collisions and rugby related game-play, while backs require speed for attacking and exploiting space. Research into the anthropometric and physiological characteristics of 35 amateur rugby league players, witnessed that conditional programmes and training procedures currently prescribed at an amateur level are not positional specific (Gabbett, 2000). Future observational research into the demands of amateur rugby league forwards and backs would allow game-play to be replicated in training routines, specific to the position.

2.8. Repeated High-Intensity Exercise

Applied Science of sport within observational based analysis has been used to objectively identify the physiological demands and repeated sprint activity (RSA). Information confirming the RSA involved in rugby league can be utilised in an applied manner to improve physical and technical performance in the most intense periods of the game (Sirotic *et al*., 2009; Austin *et al*., 2011). RSA has been hypothesized to be an influential component to the result of the game, contributing and utilised within the most intense phases of play (Dawson *et al*., 1993; Spencer *et al*., 2004; Sirotic *et al*., 2009; King *et al*., 2009; Sirotic *et al*., 2009).

Initial studies in rugby league report that RSA of players varies between competitive level and position with increasing support runs, tackles and carries of the ball (Meir *et al*., 2011; O'Conour *et al*., 1996). Research has assessed RSA in professional rugby league only, initially recording sprint activities of 8 *x* 40m (O'Conour *et al*., 1996) and 6 *x* 40m (Clark *et al*., 2003) with 30s recovery period. It is now understood that these values may be inaccurate with latter studies reporting 5 *x* 60m interspersed with 30-80s LIA (Meir *et al.,* 2001). Recent studies of rugby league have combined sprint and tackling efforts to understand repeated high-intensity exercise (RHIE) in the most physically demanding passages of play, reporting HIA of 8 *x* 42s with 50s recovery (Austin *et al*., 2011). Rugby league can vary in distance and duration and therefore research would provide information specific to the position and to enhance preparation and tactical performance. A study of amateur rugby league forwards and backs reporting RHIE and maximal values for most demanding scenarios are warranted (Austin *et al*., 2011).

2.9. Summary

Current research into rugby league has been focused at a professional level. Collectively the research has provided an insight into the demands of rugby league; however there is an understanding that physiological and technical demands of rugby league vary with playing level and position. Recent rule changes in rugby league have also modified the demands of the game; therefore a contemporaneous interpretation is warranted. Quantification of the physiological demands in rugby league can develop specific programmes of training principles, valid assessments of fitness and minimize injury and fatigue at an amateur level. A holistic approach, investigating the demands of amateur rugby league football and a comparison to semi-elite rugby league is warranted. The focus of this research therefore aims to identify the physiological demands and RHIE of forwards and backs in contemporary amateur rugby league.

CHAPTER III

METHODS

3.1. Subjects

Ten male amateur rugby league players (n=10), five forwards (open-side prop, blind-side prop, second row, hooker, loose forward) and five backs (fullback, wing, centre, standoff, scrumhalf) from the cooperative Welsh conference league participated within the investigation. The subjects were chosen randomly on the day of recording, determined upon their playing position. Subjects were not informed when they were being observed, in an attempt to maintain ecological validity. The University Wales Institute Cardiff Ethics committee approved the experimental procedures. Voluntary informed consent was provided from all individuals who participated within the study, prior to the investigation (Appendix B).

3.2. Pilot Study

Data collection procedures were confirmed and finalised within a conditioning training session. A 20min conditioned game was observed during a training session to analyse the common locomotive movements confirmed in previous studies (Beck and O'Donoghue, 2004). System development was improved following the pilot study, helping to identify the transition between locomotive movements.

3.3. Game Analysis

The analysis was conducted over a total of eleven matches (n=11) in a season and involved the observation of five forward positions and five back positions. The observer arrived in subsequent time prior to the commencement of the game and an appropriate observational point was selected. The data collection involved the verbal recording of player activity according to seven locomotive movement classifications discussed in the following chapter, using a portable dictation machine (Beck and O'Donoghue, 2004). If a selected player was interchanged strategically or because of injury, the replacement player was observed, as similar to previous studies (Duthie *et al*., 2005). If the player was sent from the field of play for an infringement a similar position was observed.

3.4. Operational Definitions

- Stationary – The player is motionless while standing, sitting, stretching or lying in a prone or supine position.
- Walking – Walking in a forward locomotive action.
- Backing – Walking in a backwards or sideward's locomotive action.
- Jogging – Slow running action in a forwards direction with no physical intent and no obvious acceleration.
- Shuffling – A backwards, lateral or on-the spot locomotion involving quick and acute movements of the feet including jogging backwards or sideways.
- Running – An elongated striding motion with purposeful acceleration above jogging and obvious effort.
- Rugby – Player is competing in an on-the-ball contest, travelling with the ball or in contact with the opposition in an attempt to regain possession. These events include carrying the ball, tackling and engaging in a scrum.

- High-intensity activity (HIA) – Most intense periods of play that require physical effort. Running, shuffling and rugby were classified as highly intensive activity.
- Low-intensity activity (LIA) – Stationary, walking, backing, jogging were classified as low intensity activity.
- Work – Four of the seven locomotive movements; jogging, running, shuffling and rugby were classified as work.
- Rest - Three of the seven locomotive movements; stationary, walking and backing were classified as rest.

3.5. Instrumentation and Analysis

The audio data was entered and analysed into the computer software system Studiocode (Version 7.5, SportsTec Pty Ltd., Sydney, Australia). A code window and template was constructed to manually code the data, assigning a button or key for each locomotive movement classification (Figure 3). Seven buttons representing each locomotive movement were exclusively linked to allow the deactivation of a previous category upon selection of a new key. Activation links were also assigned to four further classifications HIA, LIA, work and rest, providing the ability to automatically interact with multiple keys. The execution and activation of each locomotive movement automatically calculated the frequency, mean duration and distribution.

- Frequency – The total number of instances a locomotive movement was recorded over the duration of a match.
- Distribution – The relative amount of time concerned with each individual locomotive movement classification.
- Mean Duration – The average duration concerned with each individual locomotive movement classification.

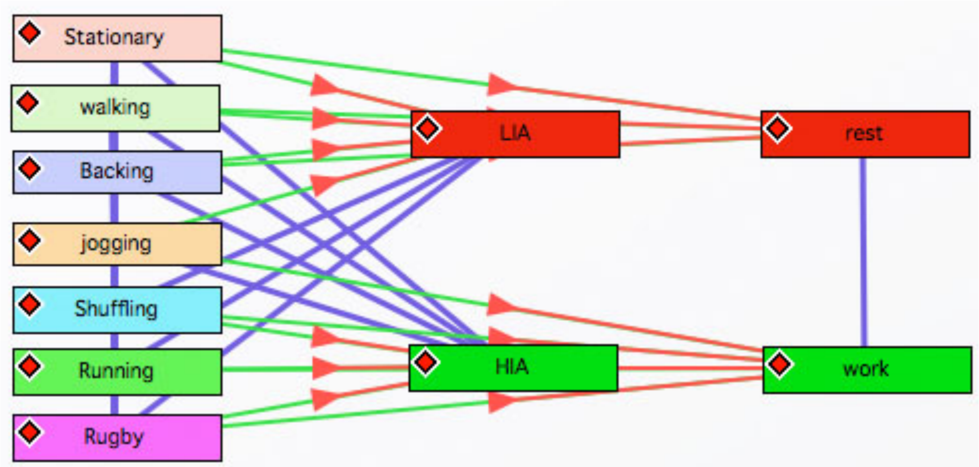

Figure 3: Code window.

Distance Estimation

The total distance travelled by each playing group was calculated through the identification of velocity profiles for forward and back positional groups, gathered from the application of electronic timing gates (Smartspeed Fusionsport, Australia). Velocity profiles were recorded through one repetition for ten players over a distance of 40m, providing the opportunity to equate total distance recorded to the nearest 0.01s. The values were calculated through the application of Microsoft Excel Spreadsheet (Microsoft Corporation, USA).

$$Distance = Speed \times Time$$

3.6. Reliability

Intra-observer and inter-observer reliability was quantified through test and retest trials, using player-cam video footage of one position for a 40min period (Sony HDV-1080, Osaka, Japan). An intra-observer reliability assessment would ensure consistency of results regarding one single observer, where inter-observer reliability would employ reliability across two observers (Gratton and Jones, 2010). The camcorder was set on the highest area using a tripod to enable the total field perimeter to be recorded (Libec TC-6, Taiwan). The video was transferred to a computer device so it allowed storage, access and analysis to be carried out conveniently. The observer coded events into Studiocode on two separate occasions, upon observing the player-cam video footage using the code window. The repeated trails took place over multiple weeks, to minimise the retention of information.

The total time agreed and disagreed was determined from numerical values presented from the Studiocode software. Additionally the values were exported into a Microsoft Excel Spreadsheet to determine Kappa reliability values. A Kappa value was used to interpret the level of reliability for the total duration that the observer was in agreement, through the use of threshold values (Altman, 1991). A kappa value previously used within medicine, evaluates the consistency of measures using a notational analysis method (Altman, 1991) (Figure 4). The kappa value is a scale of zero to one, improving as the score becomes greater. The results are demonstrated to be reliable showing a very good strength of agreement in both reliability observations.

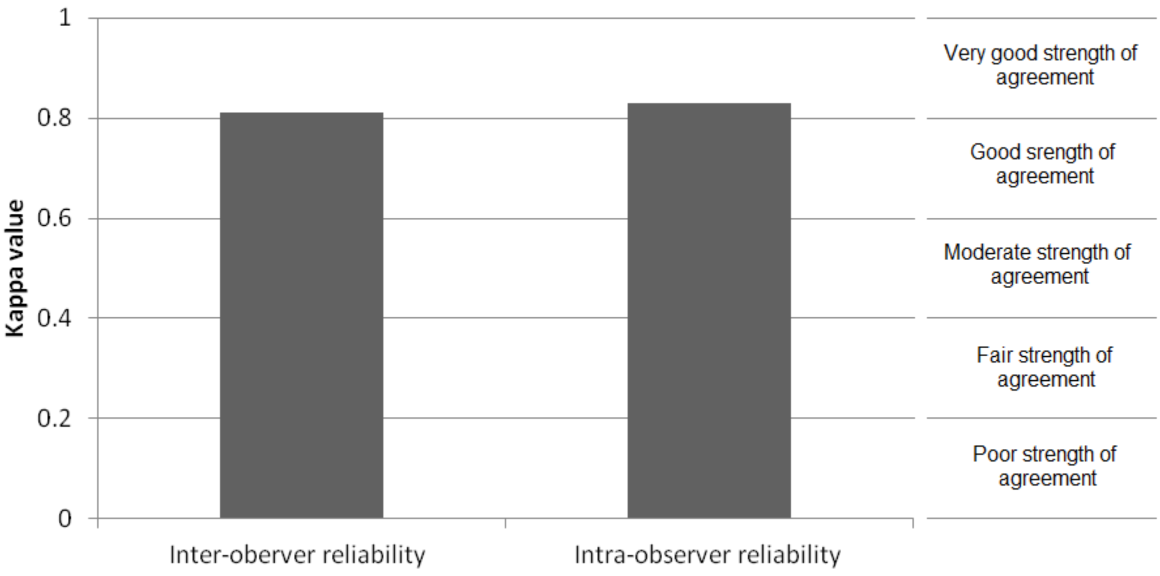

Figure 4: Kappa value for intra-reliability and inter-reliability.

3.7. Data Analysis

The ten movement data profiles were analysed to calculate the mean and standard deviation of frequency, mean duration and distribution for each locomotive movement classification. Additionally, HIA, LIA, work, rest, RSA and RHIE were calculated for forward and back positional groups. Mean velocity profiles were calculated using the duration (s) taken to travel a total of 40m and multiplied by the total time spent in each locomotive movement, providing an estimate of distance for each positional group.

Statistical Analysis

Statistical analysis was conducted through the use of Statistical Software Package for Social Sciences, version 19.0.1. (SPSS, Chicago, IL) and Microsoft Excel 2010 to export data. The non-parametric Mann-Whitney U test was used to measure the significance of difference between the forward and back groups, with a level of significance set at 95% (p<0.05). A Wilcoxon signed-ranks test investigated the significance of difference between the first and second half playing periods of the game.

CHAPTER IV

RESULTS

4.1. Amateur Rugby League and Physiological Demands

The study discovered that amateur rugby league players changed movement on 697.1 ± 63.8 occasions and every 5.5 ± 2.5s on average. The combined activities of stationary, walking, backing and jogging were classified as LIA and contributed to 35.4%, 35.1%, 7.3% and 10.8% of total time respectively. Additionally, the relative time spent in LIA (88.5 ± 3.9%) is represented in high frequencies (172.1, 193.4, 89.1 and 116.4) and mean duration (9.9, 8.4, 3.8 and 4.3s) of stationary, walking, backing and jogging locomotive movement classifications respectively.

Players were found to spend a total of 11.4% in HIA and a mean duration of 5.9 ± 1.1s. Additionally, on 14.6 ± 7.6 occasion's players were observed to complete HIA for duration greater than 10s. On a total of five occasions over ten games, players satisfied the criteria for repeated for RSA (a minimum of three sprints, with recovery duration between sprints less than 21s) (Spencer *et al.*, 2002). The mean maximal sprint duration of all positions was 12.1 ± 4.3s, additionally, travelling 84.6 ± 11m. The mean total distance for amateur rugby players was 6540.6 ± 1003.9m or 6.5 ± 1.0 Kilometers (km). The maximal distance travelled throughout one game was 8511.1m, 23.2% greater than the mean values of ten games.

It was recorded amateur rugby league players had an overall work and rest ratio (W:R) of 1:3.5. Additionally, it they were observed to spend 21.8 ± 5.9% in working activities and 78.2 ± 6.7% in recovery periods. Amateur rugby league players completed a total of 9.5 ± 3.4 RHIE bouts per game and a mean total duration of 354.5 ± 106.3. Additionally the forwards were significantly involved in greater mean duration in RHIE in the first (241.8 ± 146.3s) and second half (131.5 ± 87.8s) periods.

4.2. Frequency of Activity

Table 1 demonstrates the mean frequency of each locomotive movement classification, of both forward and back positional groups. The back positional groups were recorded to perform significantly greater frequencies of walking; however had significantly less instances of rugby related activity. A Mann-Whitney U test revealed no significant difference between the total frequencies of forwards and backs positional groups, other than walking and rugby (*p*<0.05). Additionally, there was no significant difference in the frequencies between first and second half periods.

Table 1: Frequency of locomotive movement

Locomotion	Backs (n=5)	Forwards (n=5)	All (n=10)
Stationary	174.0 ± 24.7	170.2 ± 32.3	172.1 ± 25.1
Walking	212.4 ± 24.5	174.6 ± 60.4	193.4 ± 49.4 **
Backing	98.2 ± 22.6	81.0 ± 19.1	89.1 ± 22.0
Jogging	110.6 ± 2.1	122.2 ± 17.7	116.4 ± 17.9
Running	37.8 ± 3.6	31.2 ± 7.8	34.5 ± 6.7
Shuffling	44.8 ± 11.0	41.6 ± 19.0	33.8 ± 7.1
Rugby	30.2 ± 12.3	66.6 ± 15.7	48.4 ± 23.3 **
Total	707.6 ± 70.7	687.2 ± 58.6	697.1 ± 63.8

* Significant difference between forward and back positional groups (*p*<0.05).
**Significant difference between forward and back positional groups (*p*<0.01).

4.3. Mean Duration

Table 2 displays the mean duration of each individual locomotive movement classification, of both forward and back positional groups. Forwards were quantified to spend significantly greater duration within rugby related activity however, significantly lower duration within running locomotive movements. The statistical analysis of the total mean duration of forward and back positional groups, failed to find any further significant differences.

Table 2: Duration of locomotive movement (s)

Locomotion	Backs (n=5)	Forwards (n=5)	All (n=10)
Stationary	9.9 ± 1.8	9.9 ± 1.9	9.9 ± 1.77
Walking	8.5 ± 1.1	8.4 ± 2.2	8.4 ± 1.6
Backing	3.7 ± 0.5	3.9 ± 1.1	3.8 ± 0.8
Jogging	4.5 ± 0.5	4.1 ± 0.5	4.3 ± 0.5
Running	3.9 ± 0.8	3.6 ± 1.7	3.8 ± 1.2 *
Shuffling	3.1 ± 0.7	2.8 ± 1.3	2.9 ± 1.0
Rugby	4.3 ± 0.8	6.2 ± 1.6	5.2 ± 1.5 *
Total	5.4 ± 2.2	5.5 ± 2.7	5.5 ± 2.5

* Significant difference between forward and back positional groups (p<0.05).
**Significant difference between forward and back positional groups (p<0.01).

4.4. Relative Time

The relative proportion of match time spent among the different activity classes for forward and back positional groups is displayed in Figure 5. The study observed a significant difference in forward and back positional groups for the relative amount of time in rugby related activity (z=2.6, p=0.009) and running locomotion (z=1.8, p=0.059).

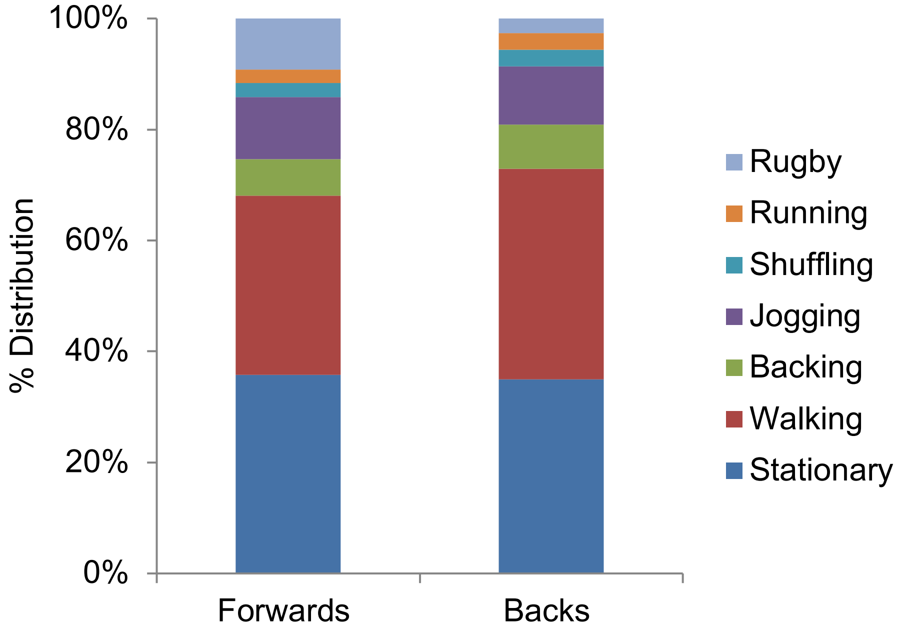

Figure 5: Average distribution of match time for backs and forwards.

4.5. Work and Rest

The ratio between W:R for forward and back positional groups are represented in Table 3. Jogging, shuffling, running and rugby locomotive movements are classified as work efforts. Forwards spent significantly longer within a working state, this was reflected within a greater frequency count (183.8 ± 38.9) and mean duration of work (20.2 ± 1.4min) when compared to backs respectively (157.8 ± 15.7 and 5.5 ± 0.4min) (Table 3).

Table 3: Work to rest ratio and total work of forward and back positional groups

Variable	Backs (n=5)	Forwards (n=5)	All (n=10)
Frequency	157.8 ± 15.7	183.8 ± 38.9	170.8 ± 31.1
Duration Work(s)	5.5 ± 0.4	6.6 ± 1.5	6.1 ± 1.0
Duration Rest (s)	20.5 ± 5.7	25.0 ± 4.3	2.7 ± 5.0
Total Work (min)	14.6 ± 0.7	20.2 ± 1.4	17.4 ± 4.7 **
% Time Work	18.3 ± 0.8	25.3 ± 6.7	21.8 ± 5.9
% Time Rest	81.7 ± 7.6	74.7 ± 9.2	78.2 ± 6.7
W:R (1:x)	4.4 ± 0.2	3.3 ± 1.3	3.5 ± 3.58

* Significant difference between forward and back positional groups (p<0.05).
**Significant difference between forward and back positional groups (p<0.01).

The relative proportion of each locomotive movement that accounts as work effort are summarised in Figure 6. Forwards are shown to contribute 44.4% of work in the form of rugby related activity, however demonstrated to spend a decreased contribution of work with running and shuffling activities, when in comparison to back positional groups (9.7, 10.5 *v* 11.9, 12.2%) respectively.

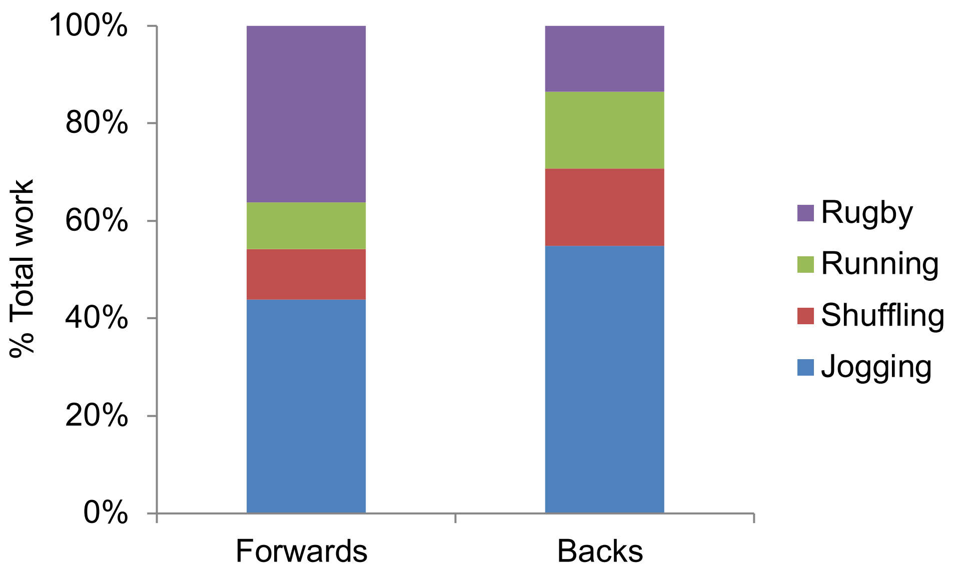

Figure 6: Contribution of locomotive movements to total work.

4.6. Repeated Sprint Activity

Averagely, backs met the criteria for “repeated sprint” activity on two occasions, whereas forwards completed three frequencies of RSA throughout a game. The mean locomotive durations presented in Table 2, display the sprint duration of forwards (3.6 ± 0.5) and backs (3.9 ± 0.8s), travelling 27.36m and 29.64m respectively. The mean count of sprints was 3 ± 0 for a repeated sprint bout, with mean recovery duration of 18.2 ± 0.8s (Table 4). The recovery consisted of 90.6% LIA and 70% active recovery, stationary (25.7%), walking (52.5%), backing (10.27%), and jogging (12.43%).

Table 4: Repeated sprint activity of forward and back positional groups

	Number of sprints	Mean time of sprint(s)	Mean time between sprint(s)
	3	16.60	5.76
	3	3.76	7.78
	3	4.29	13.74
	3	4.49	18.77
	3	5.49	17.59
Mean	3 ± 0	4.99 ± 0.71	18.18 ± 0.83

* Significant difference between forward and back positional groups ($p<0.05$).
**Significant difference between forward and back positional groups ($p<0.01$).

4.7. High-Intensity Activity

The study observed forwards spent a significantly greater mean duration within HIA (5.9 ± 1.7s), when in comparison to back positional groups (4.2 ± 0.4s) (Table 5). The backs however spent a greater duration in LIA and although insignificant had decreased instances of HIA over ten second duration. A Wilcoxon Signed Ranks non-parametric statistical test demonstrated the proportion of time spent in HIA during the first half (12.3 ± 5.2%) was significantly greater when in comparison to the second half HIA (10.2 ± 2.4%) ($p<0.05$).

Table 5: High intensity activity of forward and back positional groups

Variable	Backs (n=5)	Forwards (n=5)	All (n=10)
Frequency HIA	95.6 ± 9.2	112.4 ± 25.1	94.5 ± 36.6
Duration HIA(s)	4.2 ± 0.4	5.9 ± 1.7	5.9 ± 1.1 *
Duration LIA(s)	45.2 ± 6.1	38.2± 13.2	41.8 ± 9.7
% of match HIA	8.4 ± 0.7	14.5 ± 6.5	11.4 ± 5.5
Frequency HIA 6-10 (s)	15.0 ± 3.2	17.2 ± 3.8	16.1 ± 3.4
Frequency HIA > 10 (s)	14.0 ± 9.5	15.2 ± 6.5	14.6 ± 7.6

* Significant difference between forward and back positional groups (p<0.05)

4.8. Distance Estimation

The application of velocity profiles from ten amateur rugby league players, for each locomotive movement classification elicited an estimated distance for forwards (6091.7 ± 953.9m) and backs (6989.4 ± 924.2m). The total estimated mean displacement of forwards and backs in amateur rugby league can be seen in Figure 7. The maximal distance by forward and back position in any one given game were 7522.4 and 8511.1m, additionally 21% and 23% above the mean values of 5 games respectively.

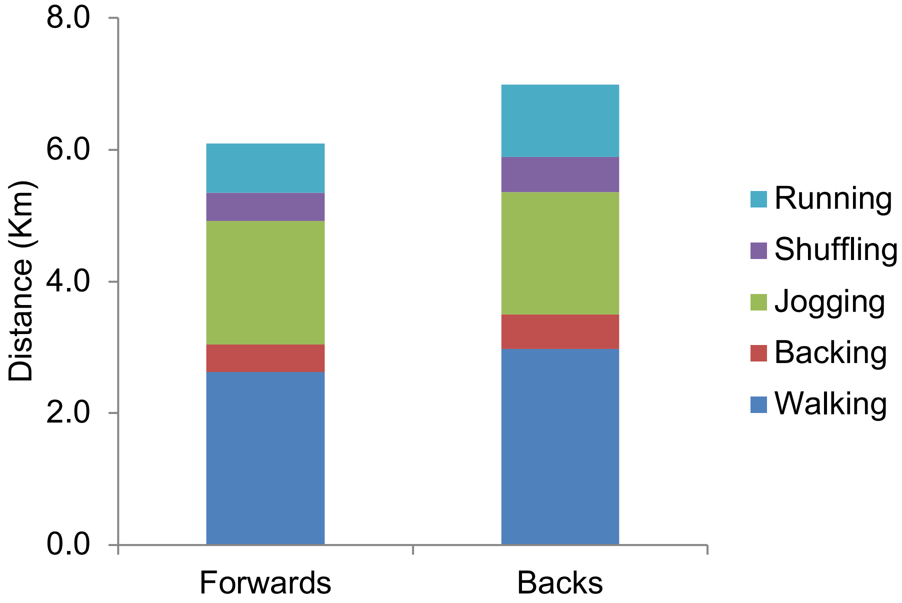

Figure 7: Estimated mean total distance for forward and back positional groups.

The mean velocity profiles for each locomotive movement in forward and backs positions are displayed in Table 6. Backs were significantly faster when covering a displacement of 40m in a running locomotion (p=0.009). Backs were recorded to travel significantly greater distances while in a running locomotion and travel a significantly greater distance throughout a whole game, when in comparison to forwards (Appendix C).

Table 6: Estimated mean total distance for forward and back positional groups

Activity	Velocity ($m.s^{-1}$)	Forwards (m)	Velocity ($m.s^{-1}$)	Backs (m)
Walking	1.65	2626.1	1.65	2977.5
Backing	1.34	421.8	1.38	518.7
Jogging	3.48	1866.9	3.77	1855.1
Shuffling	3.42	427.9	3.69	534.2
Running	6.35	749.1	7.63 **	1103.9 **
All	6091 ± 953.9		6989 ± 924.2 **	

* Significant difference between forward and back positional groups (p<0.05).
** Significant difference between forward and back positional groups (p<0.01).

4.9. Repeated High-Intensity Exercise

There was no significant difference recorded for the frequency of RHIE bouts between forward (9.4 ± 3.8) and back (9.6 ± 3.5) positional groups, or between first (5.9 ± 2.5) and second half (3.6 ± 2.3) periods. Additionally, there was no significant difference for the number of activities in a single RHIE bout or the mean maximum duration of RHIE between forwards (3.8 ± 1.2 and 42.7 ± 5.6s) and backs (3.5 ± 0.8 and 37.3 ± 6.8s) respectively. The mean total duration spent in RHIE for a game of amateur rugby league, recorded no significant difference between forwards (354.8 ± 123.4s) and backs (354.2 ± 101s). Furthermore, although insignificant the recovery periods of forwards involved active locomotion (78.4%) when in comparison to backs (65.5%).

Table 7: RHIE for forward and back positional groups

	Forwards			Backs		
	First half	**Second half**	**Match**	**First half**	**Second half**	**Match**
Total RHIE	6.0 ± 3.2	3.4 ± 1.1	4.7 ± 2.6	5.8 ± 1.9	3.8 ± 3.2	4.8 ± 2.7
Total RHIE duration (s)	270 ± 209	124 ± 29	197 ± 160	213 ± 46	138 ± 127	175 ± 98
Average maximal RHIE duration (s)		2.7 ± 5.6			37.3 ± 6.8	

CHAPTER V

DISCUSSION

5.1. Introduction

This chapter will discuss the results in relation to the overall rationale and aim of the study. The present results of this study, contribute to our knowledge of contemporary amateur rugby league, and are among the first to be conducted. The research has quantified the total distance, distribution of match time, W:R ratios, HIA,LIA, RSA and RHIE. The findings will be explained in relation to theory of performance analysis, with an interdisciplinary approach.

There has been a wealth of TMA research in professional levels of rugby league however; this study is the first to address and quantify the physiological demands of amateur rugby league forwards and backs. The conclusion of this study is of importance to any amateur rugby league team, considering the evident contrasts within injury, anthropometric and physiological of varied positional groups, however training routines are demonstrated to be comparable for all positions in amateur rugby league (Gabbett, 2000a; Gabbett, 2000b). The Aim of the study was to quantify the physiological demands of amateur rugby league forwards and backs, reporting the prevalence of intermittent activities. The research will provide support upon development of practical conditioning programmes, which are specific to both the high and low-intensity periods of the game.

5.2. Frequency of Activity

The intermittent nature of amateur rugby league is demonstrated within the high frequency count of locomotive movements (697.1), additionally can be compared to intervarsity rugby league (772.6) and elite rugby league referees (940) (Kay and Gill, 2003; Beck and O'Donoghue, 2004). However, when in comparison to rugby union half backs (432) centre (270) and forward (332), the highly intensive nature of the field sport of rugby league is highlighted (Alderson *et al.*, 1990; Beck and O'Donoghue, 2004). Additionally, in support of high frequency counts of amateur rugby league, the movements are completed on average every 5.5s. Further, this is comparable to inter-varsity rugby league, changing locomotion every 6.1s, however both are far greater than that reported for professional netball (2.2s) (Davidson and Trewartha, 2008). The requirement for greater speed, agility and quickness is demonstrated within netball given smaller court sizes; however this comparison illustrates the fundamental requirement to change locomotive movement and direction in amateur rugby league (Bangsbo *et al*., 1991).

5.3. Total Distance

The study discovered that the total mean distance covered by backs was significantly greater than that of forwards, similar to previous time-motion analysis research of professional rugby league (King *et al*., 2009; Mclellan *et al*., 2011). The calculated distances contradict and underestimate the traditional study of professional levels by Meir *et al*. (2001a) of forwards (9929m) and backs (8458m). Further, distances were overestimated when in comparison to contemporary TMA research of professional rugby league forwards (4982 ± 1185m) and backs (5573 ± 1128m) (McLellan *et al*., 2011). This discrepancy could be attributed to the inaccuracy of methods or tactical initiatives from the introduction of the limited interchange law in previous TMA research of professional rugby league (Sykes *et al*., 2009).

The significant differences observed in the distances of forwards and backs could be attributed to the distance travelled while in a running locomotion, or distribution of time in rugby related activities. The forwards were involved in greater rugby-related and HIA, potentially involving ballistic and strenuous movements in a small area and often travelled less distance before being involved in a tackle or contact situation (King *et al*., 2009). The results are understandable when considering the roles of individual positional groups. Forwards are involved in greater collisions and tackles in a close proximity to the tackle breakdown in an attempt to invade the territory of their opposition. It is believed for this reason; forwards have significantly heavier body mass in comparison to backs, to unable them to withstand greater impact forces and collisions (Gabbett, 2000a; Beck and O'Donoghue, 2004). Alternatively, backs had significantly greater frequencies of walking and spent significantly longer in LIA and in sprinting locomotion, which is comparable to studies of professional rugby league and rugby union respectively (King *et al*., 2009; Roberts *et al*., 2008). It should be noted that backs are situated on the peripheral open space of the pitch often observed to chase down opposition who break the defensive line, exploit open space and return the ball after a kick from the opposition (Gabbett *et al*., 2008; King *et al*., 2009; McLellan *et* *al*., 2011). This is also demonstrated in the anthropometric and physiological characteristics of backs, with significantly lower body mass and increased speed over 40m, when in comparison to forwards (Gabbett, 2000a).

There were no significant differences reported for the mean total distance (p= 0.95), or the distance spent running (p=0.33) and shuffling (p=0.44) of all playing positions in first and second half of match play. The distribution of time spent within rugby related activities was however, reported to be significantly different between first and second half periods, indicating the intensity of the game in amateur rugby league can decrease throughout the second half period when in comparison to the first half. A negative correlation between distance covered and HIA has been reported within soccer, which is further expected within amateur rugby league, given their poorly developed physiological and anthropometric characteristics previously reported for amateur participants (Bangsbo *et al*., 1991; Gabbett, 2000a). Having claimed that, the distribution of HIA has been reported to remain constant throughout a whole game of inter-varsity rugby league (Beck and O'Donoghue, 2004). The reported physiological characteristics and training profiles of amateur rugby league players are poorly developed and are inferior to the recommendations for the maintenance and development of aerobic activity (Gabbett, 2000a). This could potentially enhance central and metabolic fatigue of the players during the second half period, inhibiting intensity of game-play.

5.4. Running and Repeated Sprint Activity

The study observed that there was no significant difference in the frequencies of running and is comparable to the range of sprints (19-62) in soccer (Reilly and Thomas, 1976; Yamanaka *et al*., 1988; Barros *et al*., 1999) and rugby union (Docherty *et al*., 1988; Duthie *et al*., 2005), however the mean duration spent in running locomotion was significantly greater in the backs (3.9 ± 0.8s) than forwards (3.6 ± 1.6s). In agreement with King (2009) and McLellan (2011) of professional rugby, the backs and forwards on average travelled 29.6m and 22.6m respectively. Previous research has investigated the contribution of energy system during a 3s sprint, recognised as an average sprint duration of field games (Spencer *et al*., 2005) (Figure 8). Although insignificant, the mean maximal running durations of forwards (8.7 ± 1.6s) are fewer than the mean maximal running duration of backs (11.6 ± 2.8s) and has been recognised as an important variable in the provision of specific training programmes that overload the players (Spencer *et al*., 2005).

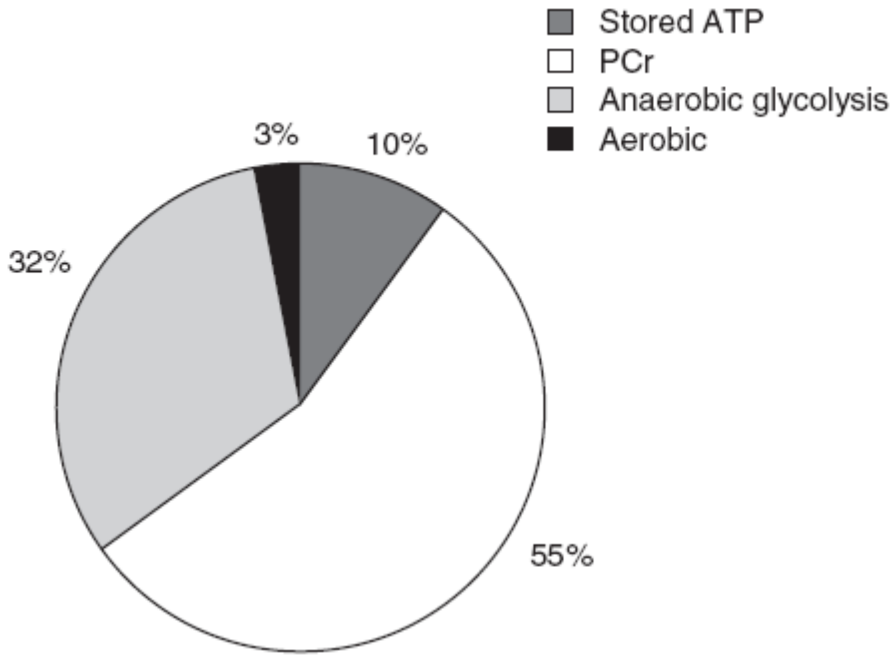

Figure 8: Estimated contribution of energy processes for a 3s sprint (Spencer *et al*., 2005).

Additionally, maximal running durations are greater than that of professional rugby league backs (7.2 ± 1.9s) and forwards (3.4 ± 1.9s) (King *et al*., 2009). This could be attributed to variation in operational definitions between “striding” and “sprinting” or the unorganised defence and greater spatial availability to amateur rugby league players, contributing to greater maximal running distances (Gabbett, 2000a; Deutsch *et al*., 2006). Considering Forwards and backs travelled 749.1m and 1103.8m, with over 31 and 37 sprints respectively, it is important to consider that RSA is part of their conditioning training programme.

A repeated sprint bout was defined as a minimum of three sprints, with less than 21s recovery (Spencer *et al*., 2002). The mean duration of repeated sprints was 4.99 ± 0.71s travelling 34.8m, with a mean recovery time between sprints 18.18 ± 0.83s. Forwards completed a total of three repeated sprint bouts in comparison to backs that completed two. The RSA is recognised as an essential component towards the outcome of the match, therefore identifying that any speed conditioning of rugby league players should involve a repetitive nature, simulating the most intense periods of the game (Spencer *et al*., 2002; Austin *et al*., 2011).

A conditioning programme of rugby league should implement the RSA for three sprints 5s, with 18s active recovery for a total of three sets for forwards and two sets for backs. Although the repeated effort demands occur infrequently throughout amateur rugby league (0-3), players should be conditioned for the most intense periods of the game (Sirotic *et al*., 2009). Laboratory studies assessing the RSA of professional rugby league players have applied protocols involving 6 x 40m and 8 x 40m (recovery periods of 30s) (O'Connor, 1996; Clark, 2003). The protocols have been previously questioned for their validity, as repeated efforts can fluctuate in distance and recovery duration (Meir *et al*., 2001; Gabbett, 2008). Considering the RSA of amateur rugby league players (3 x 34.8m) with a recovery of 18.2s, suggests previous protocols have insufficient content validity (Gabbett, 2008).

5.5. Work to Rest Ratio

W:R ratios were calculated for forward and back positional groups, for the full duration of game play irrespective of the game status, providing an objective measure of the physiological demands (Davidson and Trewartha, 2008). The recorded W:R ratios for forward and backs were 1:3 and 1:5 respectively. The results are not comparable to any previous TMA research due to a discrepancy in the definition of work. Many previous studies have calculated W:R ratio from high and low intensity activity, overseeing the involvement of jogging locomotion. The current study calculated the W:R ratios from four of seven movement classifications (jogging, shuffling, running, rugby), as it is difficult to argue jogging is not a classification of work, and would be a principal component in any conditioning programme.

Calculating W:R ratios using principles applied in previous research, were reported to be commensurable to previous studies of professional rugby league forwards (1:6 *v* 1:6) and backs respectively (1:11 *v* 1:7) and significantly different between forward and back positional groups. The training status of professional rugby league players (5.0–7.5 hours a week) in comparison to amateur (3.5 hours per week) has been witnessed as a catalyst for their excessive ability in maximal aerobic power (67.5 *v* 39.9 ml/kg/min), muscular power (54.2 *v* 38.1) and anthropometric profiles (Gabbett, 2000a). Considering the latter, it would not be uncommon if the W:R ratios of amateur level were lower than that of professional levels, experiencing increased recovery periods in succession to HIA. Given that the W:R ratios are comparable to professional rugby league indicates amateur rugby league has similar physiological requirements however, the intensity of game play may not be similar. Additionally, there is concern when comparing studies of TMA as there are often contrasts within methods and movement classifications (Spencer *et al*., 2005).

The W:R ratios indicate that amateur rugby league players are not required to perform high-intensity exercise in succession (1:1 W:R ratios) and alike professional rugby league, receive substantial time to recover through the contribution of aerobic energy processes (O'Donoghue and King, 2004; McLellan *et al*., 2011). In the main, the mean HIA periods are performed subsequently to LIA periods of forwards (5.9 and 45.2s) and backs (4.2 and 38.2s) respectively, with excessively greater recovery periods than that recorded for professional rugby league (21s). Therefore, indicating the energy required for short HIA is derived from the Adenosine Tri-Phosphate–Creatine Phosphate (ATP-PCr) while aerobic energy processes would facilitate recovery. Additionally, when HIA exceeds 6s period, anaerobic glycolytic sources satisfy the high-intensity energy demands (Wilmore and Costill, 2004; King *et al*., 2009; Sirotic *et al*., 2009; McLellan *et al*., 2011).

5.6. Repeated High-Intensity Activity

The ability to maintain RHIE without fatigue is a recognised determinant to success within any field sport and is suggested to occur during critical periods of the game. Additionally, the RHIE often occurred during the defence close to their own goal line due to the speed of the "play of the ball" following a tackle when the opposition is in possession (Spencer *et al*., 2004; King *et al*., 2009). The elevation in speed around the tackle breakdown provides decreased recovery periods (King *et al*., 2009). Specific to rugby league, a player could be expected to complete several tackles in defence, while intermittingly required to retreat 10m after each confirmed tackle. Additionally, if the player is not able to withstand the requirements, it could increase the number of infringements or leave unmarked areas within the defensive line, that the opposition could exploit (Gabbett, 2000a; Sirotic *et al*., 2009). Considering the prevalence and importance of high-intensity skills within rugby league, it is understandable why contemporary research has attempted to quantify and replicate the RHIE of field sports (Austin *et al*., 2011)

The study observed the mean frequencies of RHIE bouts over a total of 10 fixtures for forwards (9.4 ± 3.8) and backs (9.6 ± 3.5) were fewer than that recorded in professional rugby league hit-up forwards (9-17), but comparable to adjustable (2-8) and outside backs (3-7) positional groups (Austin *et al*., 2011). Furthermore, the prevalence of RHIE (3.7 ± 0.4) occurred on a greater number of instances than that recorded for the range of RSA (0-3), indicating the inclusion of shuffling and rugby related activities improves the prevalence and estimation of high-intensity exercise (Austin *et al*., 2011). The study observed mean individual high-intensity efforts of 5.9 ± 1.1s and maximal HIA bout of 19.6 ± 8.1s, considerably less than professional rugby league (35s). Additionally, the mean maximum duration of RHIE for forwards (42.7 ± 5.6) and backs (37.3 ± 6.8) demonstrate the HIA periods alone, do not accurately reflect the most demanding periods of a game.

In the present study, the recovery periods of RHIE between forwards and backs were insignificant, however forwards were demonstrated to spend greater duration in an active recovery, when in comparison to backs. As previously discussed forwards spend a greater distribution within the centre area of the field, surrounding the tackle break down. It is therefore essential that the forward positions maintain composure, providing little time for static recovery periods. The backs however on the periphery, are rarely required to follow defensive structure and therefore provides opportunity for static recovery periods (King *et al*., 2009).

5.7. Implications for Training

The requirement to specify conditioning programmes to position, has been highlighted throughout many studies in professional rugby league (Sirotic *et al*., 2009; King *et al*., 2009; Austin *et al*., 2011). Positional contrasts in the physiological demands of forwards and backs should be reflected within the conditional programme prescribed to amateur rugby league players, in an attempt to facilitate development and excellence within sport.

The current study demonstrates the majority of the game is spent within LIA, however the intermittent high-intensive periods stress the anaerobic energy pathways to re-synthesise ATP (Brewer and Davis, 1995; King *et al*., 2009). Development of aerobic energy pathways will however enhance the recovery between the repeated high-intensity bouts of exercise, where the majority of energy will be provided from an anaerobic source (Davidson and Trewartha, 2008). Amateur rugby league players would benefit from training the most intense periods reported within the analysis. The W:R ratios should be an evident component of any fitness programme however, considering the minimal training commitments of amateur rugby league players, it is of importance that the players train for the RHIE periods of the game (Gabbett *et al*., 2000).

Forwards were involved in significantly greater frequencies and duration of rugby related activity and greater durations of HIA. In previous research, it is evident however amateur forwards do not dedicate any elevated time to the development of rugby related skills (46.4 min/week), when in comparison to backs (45.1 min/week) (Gabbett *et al*., 2000). Additionally, it is evident that the back positional groups spend significantly longer and greater distribution of match time within running locomotion; however also fail to distribute greater training duration to the development of speed training (6.3 min/ week) when in comparison to forward positions (7.7 min/week). Consequently, it may be necessary for forward and back positional groups to implement specific movement patterns into their training routines to facilitate physiological adaptation or improve skill level.

6.1. Findings of the Study

In summary, the present study is the initial study to investigate the demands of amateur rugby league and although it has limitations, it has enhanced the scientific research into positional differences of amateur rugby league players. The results of the study report the physiological demands of amateur rugby league, highlighting positional differences and distinctions between amateur and professional levels. Ultimately, there are contrasts between the two positional groups of forward and backs, specifically within the frequencies, duration and distribution of HIA. It is recommended, the players of amateur rugby league complete specific training routines implementing the W:R ratios, additionally replicating the RHIE periods of the game with an active recovery; Furthermore, the backs positional groups would benefit in particular from the implementation of speed training of the maximal sprint durations and RSA. Additionally, forwards would benefit from the rehearsal rugby related skills in particular contact skills such as tackling, although the poor training durations of amateur rugby league players may limit the progression and development of such skills (Gabbett, 2000a). In conclusion, it has been demonstrated that there are obvious contrasts in the physiological demands of amateur and professional levels and between positional groups, indicating TMA data must be individualised to the specific sport, level and position (Spencer *et al*., 2005).

Recommendations for Future Research

The limitations of TMA have been highlighted in previous research (Duthie *et al*., 2003; Dobson and Keogh, 2007). The manual recording method used within this study and previous TMA research to document the movement patterns is limited, as it does not allow visual playback to repeat and re-analyse the data (Yamanaka *et al*., 1988; McErlean *et al*., 2000; Beck and O'Donoghue, 2004). The outcome of TMA research can be influenced by the experience of the observer, attention focus and level of competition (Spencer *et al*., 2005). With the variation in methods and operational definitions of locomotive movements, it is difficult to compare studies of contemporary sport that investigate the physiological demands (Spencer *et al*., 2005). Contemporary methods of TMA that employ automatic investigation could be utilised to ensure objective and accurate feedback, minimizing human error (Hughes and Franks, 2004). Furthermore, the study observed a total of ten games and therefore the sample size is considered relatively small. The investigation and observation of additional games was unfeasible due to logistical time constraints.

Additionally, it is appropriate to note the current study observed one rugby league team over a series of game, of which the results are configured. The study is a novel and could reflect the characteristics of that team; therefore the results must be interpreted with caution. Future TMA research could observe the physiological demands across numerous teams at an amateur level.

The methods applied throughout the research to calculate the total distance has previously been associated with limitations. The application of velocity profiles to calculate total distance assumes the velocities of players are constant throughout all locomotive movements. Additionally, the inclusion of the locomotive movement "shuffling" has been recognised as a limitation due to the inconsistency and nature of the movement (McInnes *et al*., 1995; Davidson and Trewartha, 2008).

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APPENDICES

APPENDIX A

UREC reference number:
01:05:2011
Title of Project: A time-motion analysis of amateur rugby league.

UWIC PARTICIPANT INFORMATION

Focus of the study

This current research has been chosen as the topic of study for my final year research project of a degree in Sport and Physical Education.

The investigation into time-motion analysis of Rugby League is an attempt to quantify the physiological demands associated with different positions within the sport at an amateur senior level.

In brief, time motion analysis has been carried on field-Based sports including rugby league at junior, semi-professional and professional levels. There has been little empirical research into the work-rate of amateur Rugby League since the enforcement of the 10meter defensive legislation. The project is an evaluation into amateur rugby league players work-rate and will examine:

(i)The work-rate between forwards and backs.
(ii)The intermittent, repeated effort demands of forwards and backs.

You're Participation

If you choose to participate, you will firstly be asked to sign an informed consent document which will allow us to carry out the research. You will be observed for 80 minutes of a game during 2011 season, on which your movements will verbally be recorded to identify your work rate. Further, light-gate systems will be used during a training session to record velocity of each locomotive movement. You will be required to perform one trial walking, backing, jogging, sprinting, and jogging backwards for 40 meters.

Are there any benefits from taking part?

Yes, you and your team will receive information regarding future training regimes that are specific to the demands of Rugby League football. It will help to develop your physiological fitness and help design test batteries for amateur rugby league teams.

Do I have to take part?

You are under no obligation to participate in this study if you do not feel comfortable with the above information.

Exclusion Criteria

If you have recently suffered from any major injuries, that will prevent you performing to optimal ability, then you will not be able to participate.

What happens next?

With this letter you'll find an informed consent document, if you are willing to participate within the study please complete the forms and return them during the next training session.

How we protect your privacy:

All the information about you and video footage will be securely stored. Confidentiality will be upheld in all circumstances. Access to names will only be accessed by the personal investigator. Consent forms will be stored for 10 years as it is a requirement of UWIC.

Have you got any questions?

If you have any further questions about the study you can contact my supervisor at the following number.

Lucy Holmes

☏ 02920 417258

✉ lholmes@uwic.ac.uk

APPENDIX B

UWIC PARTICIPANT CONSENT FORM

UREC Reference No:
Title of Project: A time-motion analysis of amateur rugby league.
Name of Researcher: Rhys Pritchard

Participant to complete this section:

I confirm that I have read and understand the information sheet dated 01:05:11 for this evaluation study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

I understand I am free to withdraw my consent and activities at any time, without giving a reason. ☐

I also understand that if this happens, our relationships with UWIC or our legal rights, will not be affected. ☐

I realise that information from the study may be used for reporting purposes, but I will not be identified. ☐

I agree for my participation within the study. ☐

Name of Participant Date

Signature of Participant Date

APPENDIX C

Table 1: Forwards and backs velocity multipliers performed over 40m.

Subject	Walking	Backing	Jogging	Shuffling	Running
1 (F)	22.9	31.2	11.4	12.4	6.4
2 (B)	24.9	30.3	10.1	10.7	5.2
3 (F)	23.5	31.1	13.1	11.1	6.3
4 (B)	24.5	29.0	10.0	10.7	5.3
5 (B)	22.9	30.4	12.1	12.7	5.4
6 (F)	24.4	31.2	9.5	11.9	6.0
7 (B)	23.7	27.9	11.0	9.9	5.3
8 (B)	25.1	27.2	9.8	10.1	5.2
9 (F)	26.5	29.5	13.0	11.7	6.8
10 (F)	23.6	26.0	10.3	11.1	5.7
Mean (F)	**24.2**	**29.8**	**11.5**	**11.6**	**6.3**
Speed ($m.s^{-1}$)	**1.6**	**1.3**	**3.4**	**3.4**	**6.3**
Mean (B)	**24.2**	**28.9**	**10.6**	**10.0**	**5.2**
Speed ($m.s^{-1}$)	**1.6**	**1.3**	**3.7**	**3.6**	**7.6**

APPENDIX D

Table 1: Wales Premier Rugby League results

Date	Opposition Team	Score	Win/Loss
14th May	Cardiff Demons	24 – 18	Loss
21st May	Bridgend Bulls	20 – 42	Loss
28th May	CPC Bears	16 – 60	Win
4th June	Newport Titans	34 – 38	Loss
11th June	Valley Cougars	30 – 32	Loss
18th June	Cardiff Demons	56 – 18	Loss
25th June	Bridgend Bulls	56 – 24	Loss
29th June	Cardiff Demons	28 - 30	Loss
9th July	CPC Bears	24 – 0	Win
16rd July	Valley Cougars	38 – 18	Win
23th July	Newport Titans	72 – 20	Loss

APPENDIX E

Table 1: Activity frequency during amateur rugby league forwards and backs

Position	Stationary	Walking	Backing	Jogging	Shuffling	Running	Rugby	Total
Fullback	141	204	121	108	57	25	18	684
Standoff	191	183	73	90	36	37	37	666
Wing	176	204	75	113	34	42	21	665
Centre	159	249	111	111	56	41	27	754
Scrum half	203	221	110	112	41	34	48	769
Prop	133	126	90	105	68	28	82	632
Prop	181	135	49	105	31	36	64	601
Second Row	206	268	94	165	36	42	82	893
Hooker	179	131	72	125	53	28	60	648
Loose forward	152	213	94	111	20	22	45	659

Table 2: Mean activity duration during amateur rugby league forwards and backs (s)

Position	Stationary	Walking	Backing	Jogging	Shuffling	Running	Rugby
Fullback	9.2	8.1	3.9	5.0	3.3	3.1	5.1
Standoff	10.7	8.7	3.9	4.3	2.3	4.6	4.6
Wing	11.0	9.5	2.9	4.8	2.5	3.7	4.8
Centre	9.0	9.2	4.3	3.7	4.3	5.0	4.2
Scrum half	7.6	6.9	3.7	4.2	3.0	3.2	3.0
Prop	10.9	6.5	5.3	4.8	4.9	5.4	8.5
Prop	12.1	9.1	4.4	4.5	2.9	4.3	6.5
Second Row	7.0	8.2	2.6	3.8	2.3	3.9	4.6
Hooker	10.2	6.4	4.2	3.7	2.3	3.1	6.6
Loose forward	9.3	11.9	3.0	3.8	1.5	3.1	4.7

Table 3: Activity distribution during amateur rugby league forwards and backs (%)

Position	Stationary	Walking	Backing	Jogging	Shuffling	Running	Rugby
Fullback	30.0	38.3	11.0	12.6	4.4	1.8	1.9
Standoff	42.5	33.1	6.0	9.7	1.7	3.5	3.5
Wing	37.8	39.4	4.4	11.2	1.7	3.3	2.1
Centre	28.5	43.7	9.1	8.0	4.6	3.9	2.2
Scrum half	35.8	35.1	9.5	10.9	2.8	2.5	3.3
Prop	31.7	22.3	10.3	11.0	6.1	2.3	6.3
Prop	45.9	25.8	4.5	9.9	1.9	3.2	8.8
Second Row	30.8	35.8	6.5	13.5	1.8	3.4	8.3
Hooker	45.4	19.1	7.5	14.1	2.9	2.1	8.8
Loose forward	28.5	51.1	5.8	8.5	0.6	1.4	4.3

Table 4: Total distance travelled during amateur rugby league forwards and backs (%)

Position	Walking	Backing	Jogging	Shuffling	Running	Total
Fullback	2751.2	661.1	2060.8	711.9	595.4	6780.6
Standoff	2640.7	403.0	1766.9	302.5	1290.13	6403.3
Wing	3183.4	298.1	2075.9	313.5	1229.0	7100.0
Centre	3796.9	662.5	1582.3	889.0	1580.2	8511.1
Scrum half	2515.3	568.6	1789.5	453.7	824.4	6151.8
Prop	1705.3	637.7	1779.9	975.6	685.6	5784.2
Prop	2037.4	286.7	1637.4	311.5	977.6	5250.7
Second Row	3721.3	333.6	2155.4	277.2	1034.7	6091.4
Hooker	1480.5	467.6	2301.41	472.4	615.7	5337.7
Loose forward	4185.6	383.1	1460.1	102.6	431.6	6563.3

APPENDIX F

Statistical Analysis Results

Mann-Whitney U Test: Frequency of Activities of forwards and backs.

Locomotion	Z Score	Asymp. Sig
Stationary	-0.104	0.917
Walking	-2.402	**0.016**
Backing	-0.940	0.347
Jogging	-0.000	1.000
Shuffling	-0.736	0.462
Running	-0.838	0.402
Rugby	-2.402	**0.016**
All	-0.065	0.948

Mann-Whitney U Test: Duration of Activities of forwards and backs.

Locomotion	Z Score	Asymp. Sig
Stationary	-0.104	0.917
Walking	-0.210	0.834
Backing	-0.731	0.465
Jogging	-0.420	0.674
Shuffling	-1.156	0.248
Running	-1.984	**0.047**
Rugby	-2.193	**0.028**
All	-0.447	0.655

Mann-Whitney U Test: Work to Rest Ratio of forwards and backs.

Locomotion	Z Score	Asymp. Sig
Frequency of work	-1.149	0.917
Duration of Work (s)	-0.940	0.347
Duration of Rest (s)	-1.456	0.117
Total Work (min)	-2.611	**0.009**
% Time Work	-1.567	0.117
% Time Rest	-0.940	0.347
Work to Rest Ratio	-1.567	0.117

Mann-Whitney U Test: Distribution of locomotion of forwards and backs.

Locomotion	Z Score	Asymp. Sig
Stationary	-0.104	0.917
Walking	-0.940	0.347
Backing	-0.000	1.000
Jogging	-0.629	0.530
Shuffling	-0.522	0.602
Running	-1.886	**0.059**
Rugby	-2.619	**0.009**
All	-0.313	0.754

Mann-Whitney U Test: Total distance of forwards and backs.

Locomotion	Z Score	Asymp. Sig
Walking	-0.731	0.465
Backing	-1.149	0.251
Jogging	-0.104	0.917
Shuffling	-0.731	0.465
Running	-2.402	**0.016**
All	-2.402	**0.016**

Mann-Whitney U Test: Light-gate velocity profiles of forwards and backs.

Locomotion	Z Score	Asymp. Sig
Walking	-0.629	0.530
Backing	-1.152	0.249
Jogging	-0.940	0.347
Shuffling	-1.576	0.115
Running	-2.627	**0.009**
All	-2.627	**0.016**

Mann-Whitney U Test: HIA and LIA of forwards and backs.

Locomotion	Z Score	Asymp. Sig
Frequency of HIA	-1.257	0.209
Duration of HIA (s)	-2.193	**0.028**
Duration of LIA (s)	-1.358	0.175
% of match HIA	-1.567	0.117
Frequency HIA (6-10s)	-0.738	0.461
Frequency HIA (>10s)	-1.366	0.176

Mann-Whitney U Test: RHIE of forwards and backs.

Locomotion	Z Score	Asymp. Sig
Total Time HIE	-1.149	0.251
Total Time RHIE	-0.210	0.834
Frequency of RHIE	-1.358	0.175
Instances of HIE per	-1.622	0.105
RHIE	-0.104	0.917
RHIE Recovery	-1.567	0.117
RHIE Active Recovery		

Wilcoxon Signed Ranks Test: 1st and 2nd half frequencies.

Locomotion	Z Score	Asymp. Sig
Stationary	-0.561	0.575
Walking	-0.357	0.721
Backing	-1.248	0.212
Jogging	-0.408	0.683
Shuffling	-0.307	0.759
Running	-0.665	0.506
Rugby	-1.381	0.167

Wilcoxon Signed Ranks Test: 1st and 2nd half distribution.

Locomotion	Z Score	Asymp. Sig
Stationary	-2.293	**0.022**
Walking	-0.866	0.386
Backing	-0.866	0.386
Jogging	-0.663	0.508
Shuffling	-0.764	0.445
Running	-1.070	0.285
Rugby	-2.091	0.037

Wilcoxon Signed Ranks Test: 1st and 2nd half distance.

Locomotion	Z Score	Asymp. Sig
Walking	-0.764	0.445
Backing	-0.663	0.508
Jogging	-0.357	0.721
Shuffling	-0.764	0.445
Running	-0.968	0.333
Total Distance	-0.051	0.959

Wilcoxon Signed Ranks Test: 1st and 2nd half RHIE.

Locomotion	Z Score	Asymp. Sig
Total Time RHIE	-1.886	**0.059**
Frequency of RHIE	-1.793	0.0.73
RHIE Time Backs	-0.944	0.345
RHIE Time Forwards	-1.753	0.080
RHIE Active Recovery	*-1.567*	*0.117*