University of Alberta

Physiological demands of women's rugby union: Time motion analysis and heart rate response

by

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To my Family:

For your endless love, support and

friendship, it means the world to me.

Abstract

The aim of this study was to determine the physiological demands of women's rugby union match play using time motion analysis and heart rate response. Thirty-eight Alberta premier club level female rugby players ages 18–34 years were video taped and heart rates monitored for a full match. Performances were coded into 12 different movement categories: 5 speeds of locomotion (standing, walking, jogging, striding, sprinting), 4 forms of intensive non-running exertion (ruck/maul/tackle, pack down, scrum, lift) and 3 discrete activities (kick, jump, tackle). The main results revealed that backs spend significantly more time walking and sprinting whereas forwards spend more time in intensive non-running exertion and jogging. Forwards displayed higher mean heart rate throughout the match and spent more time above 80% of their maximum heart rate than backs. Women's rugby union is characterized by intermittent bursts of high intensity activity where forwards have very different match physiological demands than backs.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Women's rugby is continually growing in popularity and constantly gaining participants every year. There are currently women competing at the national, provincial, university, club, high school and recreational levels across Canada (Rugby Canada, 2004). This rise in popularity is evident by the increase in the number of registered female participants internationally. The 2005 international season statistics showed a 9, 13 and 15 percent increase in female pre-teen, teenage and open grade players respectively. In total there were 39,619 rugby union female athletes in competition during the 2005 season which represents just over a third of the male total of 102,386 (International Rugby Board, 2005).

The previous literature concerning rugby union covers a variety of topics such as the physiology of the game and its players, rugby ratings, performance indicators, muscle damage due to contact as well as the effect of ball carrying technique on sprint speed (Bracewell, 2003; Deutsch, Kearney & Rehrer, 1998; Grant, Oommen, McColl, Taylor, Watkins, Friel, Watt & McLean, 2003; James, Mellalieu & Jones, 2005; Olds, 2001; Takarada, 2003). However, the large majority of these papers have only studied male rugby union players. To date, there are only a few studies that have been completed on the physiological characteristics of female rugby players and it has been suggested that women's rugby play may be different from men (Kirby and Reilly, 1993; Nicholas, 1997; Gabbett, 2007).

1.2 Significance of Study

Despite the popularity, there are few scientific studies that have explored women's rugby and none of the current literature has investigated movement patterns of women's rugby union using time motion analysis. The growth of women's rugby union has lead to an increased competitiveness in the game resulting in a need for the development and implementation of sport specific conditioning programs within a periodized plan. In order to accomplish this, the specific physiological demands of women's rugby union need to be quantified. Technological advancement has allowed researchers to take a more scientific look at the physiological demands of many different sports using time motion analysis, blood lactate analysis, distances covered and heart rate measurements. An application of this study would be to gain further understanding of the demands of women's rugby so that periodized strength and conditioning programs could be developed that are position specific. This information would potentially provide the basis for coaches and athletes to improve performance by increasing physiological tolerance to match demands and reducing errors in skill execution due to fatigue as well as decrease occurrence of injury.

1.3 Purpose & Hypothesis

The purpose of this study was to use time motion analysis to determine and quantify movement patterns as well as monitor heart rates during competition to assess the physical demands and heart rate response of female premier club rugby union athletes. It was hypothesized that there would be no significant difference in the movement categories, work and rest intervals or heart rate measurements between the forwards and the backs positional groups. An aim of this study was to attempt to provide new knowledge that might aid in the understanding of the physiological demands specific to the female game and its various positions. Furthermore, the data gathered in this study may have specific implications on the structure and focus of women's rugby training sessions as well as the conditioning programmes of the various positions.

1.4 Delimitations

The participant sample consisted of female premier division club athletes of the following positions: props and locks (tight four), back row forwards and hooker (back row), fly half and centers (inside backs) and wings and fullback (outside backs). Female subjects were chosen because of their under representation in the literature to date. Premier division athletes were the focus because it is the highest level that has regular league play as well as a large population from which to obtain a sample. In total there were 12 game days (Appendix A) in the 2006 season to gather data from 3 Edmonton club teams. Select teams such as the city and provincial teams only have one main tournament per summer and because of this, they were not selected since this would have severely limited the number of games and participants available.

Time motion analysis was conducted on the recorded video and provided data used to calculate the total and mean duration, the frequency and the percent of game time of each movement as well as the work and rest variables. Team heart rate monitors (Polar Electro Oy, Kempele, Finland) provided heart rate response for an entire match where match minimum heart rate, maximum heart rate and mean heart rates of the whole match and the individual halves were calculated.

1.5 Limitations

According to the Edmonton Rugby Union league schedule there are 72 regular season games in total that can be observed from May to September. However, 6 games are scheduled every Saturday at the same time at different fields throughout the city and province. In order to reduce seasonal effect all matches were recorded after one full month of competition, from June to September. By the second month of the season all teams had played 5 games as well as had 8-10 team training sessions. Due to equipment access and data acquisition logistics, only 4 participants were video recorded during each of the 10 matches. One match occurred during a deluge of rain and another match was out of town where in both cases only heart rates were gathered. The team polar heart system was set up to record 10 heart rates per match however all 3 teams had a consistent starting side which limited the number of collected data sets. Backs were more prone to having the heart rate monitor move out of place occasionally which provided unusable data. Substitutions also limited the number of full match heart rate data as a result a final sample size of 38 participants that were video recorded, of which, only 27 whole match heart rates were collected.

1.6 Definition of Rugby Union Terms:

1) **Try:** When an individual places the ball down across the end line (try line), it is worth 5 points. A try is similar to a touchdown in Canadian tackle football

except downward pressure on the ball to make contact with the ground is required.

2) **Conversion:** A kick that follows a try worth 2 points. It can be a drop kick or place kick and must occur on a perpendicular line from where the try was gained (distance may very depending on the kickers preference).

3) **Lineout:** A lineout occurs at the site of the ball exiting the field by the side line, also called going into touch. A lineout involves 2-7 forwards in a straight line perpendicular to the touch line one meter away from the opposition. It is the means by which the ball is re-entered into play.

4) **Ruck:** A ruck is formed when the ball is on the ground and one or more players from each team are on their feet and in physical contact, closing around the ball between them (International Rugby Board, 1998).

5) **Maul:** A maul is formed by one or more players from each team that are on their feet and in physical contact closing round a player who is also on their feet and in possession of the ball (IRB, 1998).

6) **Tackle:** A tackle occurs when a player, who is carrying the ball, is held by one or more of the opponents so that they are brought to the ground or the ball comes in contact with the ground (IRB, 1998). A tackle constitutes the participant taking the opposition completely to ground as the primary tackler.

7) **Pack Down:** This term represents exertion that occurs prior to the actual scrum in the form of binding to other players and holding a coiled body position (very low squat).

8) **Scrum:** A scrum is formed at the place of infringement constituting eight forwards from each team. The forward formation starts in a crouched position and engages into contact with each other on the referee's signal and awaits the release of the ball and then commences contesting for possession (Deutsch et al., 1998; IRB, 1998).

9) **Bind:** A term used to describe a physical connection between teammates prior to a scrum involving the action of grabbing other jerseys and actively holding on tight.

10) **Lifting:** This action occurs during lineouts and is also referred to as boosting. When the hooker (#2) throws the ball into play from the side line (touch line) it is caught by a player who jumps and is simultaneously lifted by two players, one in the front and the other from behind.

11) **Jumping:** This occurs primarily in lineouts as explained above in the lifting definition and at times players jump to receive a ball or block a kicked ball in the air.

12) **Intense non-running Exertion:** Constitutes physical exertion in the form of a ruck, maul, tackle, pack down, scrum or lift. It is has also been referred to as static exertion (Duthie et al., 2005; Deutsch et al., 1998; Roberts et al., 2008).

CHAPTER 2

REVIEW OF LITERATURE

2.1 A Brief History of Rugby Union

The game of rugby first appeared at the Rugby school in England where students were largely responsible for creation and implementation in the games they played (Rugby Football History, 2007). The first set of written rules was published in 1845 by students at the Rugby school (Wikipedia contributors, 2008). The first Rugby Football Union was founded in 1871 which was followed by the approval of the first laws of the game. The first official match took place between England and Scotland in Edinburgh in 1871, where Scotland emerged the victor.

In 1886 the International Rugby Football Board (IRFB) was formed and is known today as the IRB. Their responsibilities included overseeing matches between home unions and were also a recognized law making body. An important year in rugby union history was 1995 when the IRB agreed to fully professionalize rugby union (Wikipedia contributors, 2008).

In Canada, rugby made its first appearance in the 1860's thanks primarily to immigrants. In the year 1864, Montreal held the first documented game and the first set of rules were published in Toronto. The first rugby club was formed in Montreal a few years later. The Canadian Rugby Football Union was founded in 1880 and rugby itself was introduced into Alberta 10 years later (Rugby Canada, 2004).

In 1983 the Women Rugby Football Union (WRFU) was formed which encompassed England, Ireland, Scotland and Wales and included 12 founding teams (Wikipedia contributors, 2008). The 1970's marked the emergence of women's rugby in Canada and provincial and national championships followed in the 80's (Rugby Canada, 2004). The first official Women's Rugby World Cup occurred in 1998. It was held in Amsterdam where 16 teams competed for the title (Australia, Canada, England, France, Germany, Ireland, Italia, Kazakhstan, Netherlands, New Zealand, Russian Federation, Scotland, Spain, Sweden, USA & Wales) (Wikipedia contributors, 2008).

2.2 Energy Systems

Rugby union, like any other physical activity requires energy. There are three different processes or energy pathways that act collectively to produce energy: ATP-PC system, lactic acid system and the aerobic system. The proportion with which each contributes is dependent on the intensity and duration of the activity (Gastin, 2001).

The ATP-PC system is the first of two anaerobic energy systems that provides an immediate high rate of energy by the breakdown of adenosine triphosphate (ATP) and phosphocreatine (PC) that are stored within the muscle (Gastin, 2001). This system achieves peak power in the 1-2 second range and has a capacity of around 10 seconds with maximal effort (Gastin, 2001). There are no fatiguing by-products created by the ATP-PC system, which allows for a full recovery of the ATP-PC stores in 2-5 minutes respectively (Foss & Keteyian, 1998). Rugby specific examples of the use of the ATP-PC system would be a tackle, jump, lift or sprint.

The second anaerobic system to contribute energy is the lactic acid system. In this system glycolysis and glycogenolysis rely on glucose and glycogen, respectively, to produce a small amount of ATP at a fairly high rate (Gastin, 2001). The lactic acid system is at peak power after 5 seconds of maximal exercise and has a capacity to supply energy for 45-120 seconds (Gastin, 2001). This process, however, produces lactic acid as a by-product, which is a contributing factor to muscular fatigue. Muscle H^+ levels require 30-60 minutes for full recovery (Foss & Keteyian, 1998). This system is stressed during static exertion as well as with repeated sprints or tackles.

Finally the last energy producing process is the aerobic system. This system utilizes oxygen to create a large amount of energy from the breakdown of carbohydrate, fat and protein (Gastin, 2001). At 75 seconds, half of the energy for maximal exercise is supplied by this system and by 3 minutes it is estimated to supply 100% of the energy requirements for exercise. Once the aerobic system is initiated, long-term energy is supplied at a steady but sub-maximal rate. The aerobic system is crucial to sustained submaximal activity as well as recovery from anaerobic bouts of exercise. In summary, without these three successively overlapping systems the energy demand of exercise would not be met (Gastin, 2001).

2.3 Rugby Union Game

Rugby union is an 80-minute game that has no set stoppages in play except for the 5 minutes during half time. Possible unpredictable stoppages occur in the event of a try or injury. A rugby team consists of 15 players each with varying roles and responsibilities (Reilly, 1997). All positions have a designated number: 1- loose head prop, 2- hooker, 3- tight head prop, 4- left lock, 5- right lock, 6- left flank, 7- right flank, 8- number eight, 9- scrum half, 10- fly half, 11- left wing, 12- inside centre, 13- outside centre, 14- right wing, and 15- full back (Figure 1 – Image modified from Gastonia Rugby Football Club, 2008).

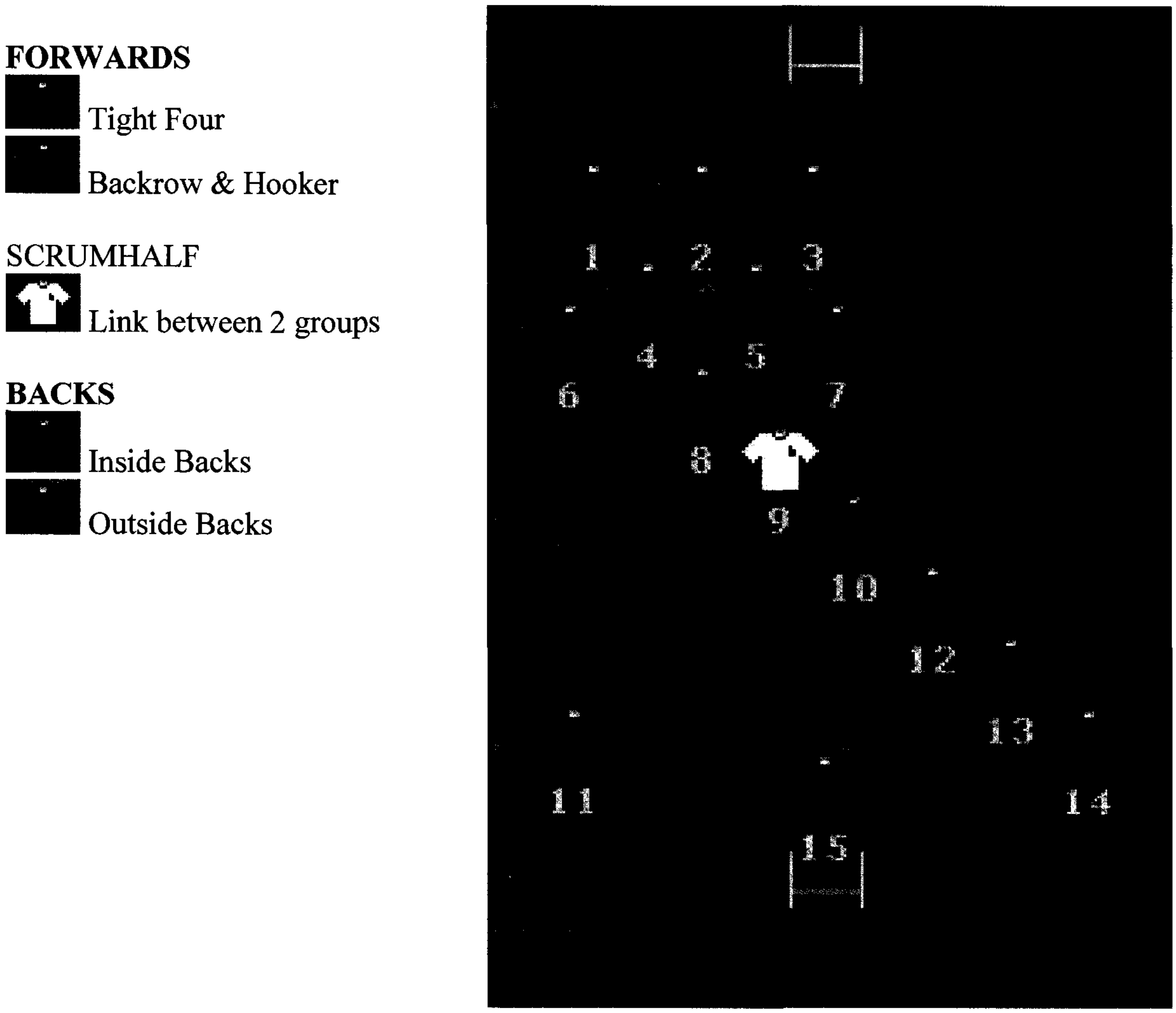

Figure 1. Arial view of a rugby pitch with all positions numbered 1-15. The colour categories represent four subgroups: Dark red - Tight Four (T4), light red - Back row & Hooker (BR), light blue - Inside Backs (IB), dark Blue - Outside Backs (OB). All the red jerseys, both light and dark are forwards; all the blue jerseys both light and dark are backs and the white jersey represents the scrumhalf which was not filmed in this study.

The primary and largest division of the 15 rugby union positions is that of forwards and backs. Some studies divide the two main groups even further into tight four, backrow, inside backs and outside backs (Duthie, Pyne & Hooper, 2005; Deutsch, Maw, Jenkins & Reaburn, 1998; Doutreloux, Tepe, Demont, Passelergue & Artigot, 2002; Deutsch, 2007; Roberts, Trewartha, Higgitt, El-Abd & Stokes, 2008). Forwards are positions 1-8 are and their major responsibility is to gain or maintain possession of the ball (Nicholas, 1997; Reilly, 1997; Duthie, Pyne & Hooper, 2003). Backs are positions 9-15 and are primarily ball carriers and responsible for the majority of the scoring (Nicholas, 1997; Duthie et al., 2003). The scrumhalf is not included in these subgroups because of their mixed positional responsibilities that are quite different from all other categories (Deutsch et al., 1998; Duthie et al., 2005).

2.4 Time Motion Analysis

Time motion analysis involves video recording match play that is later analyzed by the researcher with the use of computer program software that can track several different movement categories. Video recording is optimal for complex movement pattern analysis as it can be slowed down or repeated as needed (Martin & Bateson, 1993). Individuals are normally filmed throughout an entire game providing a continuous recording of the frequencies, mean and total durations in each activity and allows for work rate and percent game calculations. Additional information on possible changes in performance due to fatigue can also be provided (Martin & Bateson, 1993; Duthie et al., 2005; Roberts et al., 2008). The analysis of movement patterns and work rates provide useful information concerning the energy demands specific to the sport (Duthie et al., 2003; Duthie et al., 2005; Reilly & Gilbourne, 2003; Deutsch et al., 2007). Sports such as Gaelic football (Florida-James & Reilly, 1995; Keane, Feilly & Hughes, 1993), association football (Davis & Brewer, 1993; Reilly & Thomas, 1976; Rienzi, Drust, Reilly, Carter & Martin, 2000), field hockey (Reilly & Borrie, 1992; Spencer, Lawrence, Rechichi, Bishop, Dawson & Goodman, 2004), rugby league (Coutts, Reaburn & Grant, 2003; Clark, 2002; Gabette, 2005) and rugby union (Catterall, Reilly, Atkinson & Coldwells, 1993; Deutsch et al., 1998; Docherty, Wenger & Neary, 1988; Doutreloux et al., 2002; McLean, 1992; Rienzi, Reilly & Malkin, 1999; Deutsch et al., 2005; Deutsch et al., 2007; Roberts et al., 2008) have all been quantified by time motion analysis.

2.5 Rugby Union Time Motion Analysis

Since there has not been any research published on the physiological demands of women's rugby union, the literature on the men's game will be reviewed. Docherty et al., conducted a study in 1988 specific to centers and props (n=27) at the first division and representative levels. It was found that centres spent more time in intense running and props in intense non-running activities. They concluded rugby union has an intermittent nature and suggest loading phosphagen stores through oral supplementation since the average match activity was under 10 seconds in duration and blood lactate measurements were found to be quite low. This would indicate that the major source of energy was derived from the ATP-PC system.

McLean (1992) conducted time motion analysis on entire televised games at the international level. Work rate was utilized in order to determine the game demands. This approach is still quite unique as all the other literature on time motion analysis of this sport focus on individual measurements usually in reference to a specific position. Due to the high work rates and blood lactate measurements, McLean observed that there was greater stress placed upon the anaerobic glycolytic system than once thought.

Elite under 19 rugby athletes (n=24) studied by Deutsch et al. (1998) revealed that backs cover significantly greater distances and spend short periods of time at high intensities where forwards maintain a higher level of exertion due to their involvement in static high intensity activities. After taking into account heart rates, blood lactates and movement statistics, it was summarized that a good aerobic base was required by all positions, especially backs so that recovery is facilitated and fatigue minimized. The findings of this study were almost identical to a paper published four years later by Doutreloux et al. (2002). The work to rest ratio of the props and locks and back row forwards were 1:1.4 and 1:1.2 respectively whereas the inside and outside backs were found to be 1:2.7. Therefore the backs had longer periods of rest to recover between their bouts of work compared to forwards.

In 2005, Duthie et al. published a study on elite super 12 athletes (n=41). Entire games were filmed and position specific data gathered allowed for a comparison between the 40-minute halves. According to these findings, the game is represented by repeated high intensity efforts and short periods of rest (<20s). Forwards performed more work activities due to static exertion and backs perform more sprints. There was no significant difference between the halves; therefore, they concluded that fatigue does not affect the type or amount of activity. The only significant differences between subgroups occurred in the percentage of game time spent at work and at rest. The inside backs spend more time at work then did the outside backs. Backs also tended to stride more then the props however this did not attain significance.

The latest paper published by Deutsch et al., (2007) in this area involved 29 of the New Zealand Otago Highlanders super 12 team. The purpose was to quantify movement patterns with which position specific training and fitness testing could be developed. Deutsch et al., (2007) further developed his coding movement groups to include 12 categories in total: standing still, walking, jogging, cruising, sprinting, utility, ruck/maul, tackling, scrumming, kicking, jumping and passing. Once again these latter findings showed that all positions place a high amount of stress on all energy systems however the anaerobic glycolytic pathway plays a larger role than previously reported. More specifically forwards repeated participation in non-running intense activities involves a greater demand on the glycolytic energy system in comparison to backs. Work to rest periods analyzed indicated that for training sessions the work to rest intervals should be designed to promote maximal lactate production and increase fatigue resistance.

The most recent time motion analysis study completed was by Roberts et al.,(2008) on elite English rugby union match play (n=29). This study implemented a new system involving 5 stationary cameras that covered different areas of the field. The data was then reconstructed into a two dimensional plane where player movement was recognized and measured by a specific analysis program based on speed of movement. The purpose of the study was to assess the physical demands of the match specific to position but in a more accurate and reliable way than in previous studies. This is the first study to concentrate on changes in high intensity running through out an entire match with focus on distances covered. Results showed that the backs covered more total distance during a match as a result of more distance covered walking and high intensity running than forwards. The whole match was separated into 10 minute intervals and compared for distances traveled in order to observe a possible fatigue factor. The first ten minutes was shown to cover more total distance than the 5^{th} and 7^{th} ten minute interval however the extra distance in the first ten minutes was completed at a lower intensity therefore not a factor of fatigue.

In summary, male rugby time motion analysis studies all suggest significant variance between forwards and backs and a contribution from all three energy systems, with the majority of studies suggesting that the anaerobic systems played a more predominate role. Generally, backs covered more distance in a game, had longer rest periods and spend more time sprinting. Forwards performed more work activities due to intense non-running exertion and had shorter periods of recovery. However, Lakomy, Dabinett and Nevill (2000) analyzed the physical and physiological differences between male and female athletes and found that generally men have greater speed, strength and power. This would directly influence the pace of the game as well as how it is played. Even though there have been differences found between forwards and backs in men's rugby union, such differences have not been examined in women's rugby.

2.6 Physiological Measures

Blood lactate

Blood lactate measures have been used as an indirect measure of anaerobic glycolysis in a few of the rugby time motion analysis publications. There are many logistical difficulties encountered when collecting blood samples during competitive rugby. First, sampling is dictated by stoppages in play such as after injury or a try, which can be unpredictable, or at half time or at the end of the game (Duthie et al., 2003). Samples taken at these times are only indicative of the most recent activity and intensity of play undertaken by the players (Duthie et al., 2003). They are not actually representative of the overall physiological stress of the match. This must be considered when reviewing the blood lactate results found in Docherty et al., (1988). Post-game mean blood lactate was recorded at 2.8 mmol/L which is slightly above resting levels (0.5-1.0 mmol/L) (Foss & Keteyian, 1998). McLean, (1992) however took blood samples during injuries and penalty kicks and found mean lactate levels of 5.1-6.7 mmol/L. Deutsch et al., (1998) also found similar mean blood lactate readings of 4.7-7.2mmol/L. These results suggest more of an anaerobic contribution than the data presented by Docherty et al., (1988). A positive relationship between VO_{2max} and the rate of blood lactate clearance was established from the results of the elite rugby players (Deutsch et al., 1998). This suggests that higher aerobic power decreases recovery time from intense exercise by increasing the speed of blood lactate removal and associated by-products of anaerobic glycolysis, such as the buffering of H^+ ions (Duthie et al., 2003).

Finger tip blood lactate measures are convenient but the samples taken are not necessarily a reflection of match concentrations. Validity of this measure, therefore, is questionable. If periods of low intensity activity permit lactate the time to efflux from the working muscle and metabolize, a blood sample would underestimate the concentration of the lactate in the muscle during actual intense exercise or activity (Reilly, 1997).

Distance

Determining distances covered during a rugby game is challenging. Some investigators estimate velocities or distance with visual cues and field markings (McLean, 1992). However these methods require assumptions that can be avoided when measuring the duration of an activity (Duthie et al., 2005). A new time motion analysis system has been implemented by Roberts et al., (2008). It involves 5 stationary cameras that are calibrated so that the data can be reconstructed on a 2D plane and analyzed by specialized speed recognition software through which distances are calculated. This new system has potential to be more widely accessible in the future. There is alternative technology available, such as accelerometers to calculate distances, but these instruments cause logistical problems due to the contact nature in the sport of rugby union. Global positioning systems can also be used to track movements across a field however velocity cannot always be calculated accurately over short distances.

Heart rate

Direct determination of oxygen consumption during rugby match-play would help determine a portion of the physiological requirements of the sport on the human body. However, due to the contact nature of the game, measuring oxygen uptake by indirect open circuit spirometry with portable laboratory equipment would prove not only hazardous but also possibly alter the performance being measured.

A more indirect but practical method of estimating aerobic intensity during game situations is using heart rate measurement. This method is based on the assumption that heart rate and oxygen consumption are linear at all intensity levels when actually they are curvilinear at very low and very high intensities (Achten & Jeukendrup, 2003). This can cause up to a 20% deviation from the actual value (Achten & Jeukendrup, 2003). Other sources of error concerning heart rate measurement are estimation of maximal heart rate, cardiovascular drift throughout a game due to dehydration and peripheral vasodilation due to the delay in heart rate response to quick changes in intensity (Achten & Jeukendrup, 2003). Under these circumstances, heart rate measurements may not provide a completely accurate representation of exercise intensity at that point in time. However, it is a reasonable gauge of whole body stress and exercise intensity during game situations (Achten & Jeukendrup, 2003).

New portable heart rate technology has been shown to be an accurate and practical way to record heart rate during stressful physical activity (Hiilloskorpi, Fogelholm, Laukkanen, Pasanen, Oja, Manttari & Natri, 1999). More specifically, it has also been determined to be both valid and reliable in a field setting (Achten &

Jeukendrup, 2003; Strath, Swartz, Bassett, O'Brian & King, 2000). A satisfactory estimate of oxygen uptake can be made from heart rate when it is applied to healthy young to middle aged populations and not to a specific individual (Achten & Jeukendrup, 2003; Hiilloskorpi et al., 1999; Luke, Maki, Barkey, Cooper & Mcgee, 1997).

Many researchers have used heart rate response to describe and compare the physiological demands of various field sports such as association football, rugby league and rugby union (Catterall et al., 1993; Coutts et al., 2003; Deutsch et al., 1998; Doutreloux et al., 2002). Match heart rates for rugby league players in 2003 showed that more time is spent in moderate to high work intensity than rugby union players (Coutts et al., 2003). Two separate studies found that rugby union forwards spend more time in high exertion (85-95% HR_{max}) than backs (Deutsch et al., 1998; Doutreloux et al., 2002). Davis and Brewer (1993) reviewed literature on the physiological demands of women's soccer and reported an average heart rate of 176 $b \cdot min^{-1}$ during 4 vs. 4 game play.

Blood lactate, distances and heart rate have all been used along with time motion analysis in an attempt to increase knowledge of the physiological demands of rugby union. Most studies have suggested that there are significant differences between forwards and backs in all four areas. Collective results indicated that there is a contribution from all three energy systems however the anaerobic systems appear to play a more predominate role.

CHAPTER 3

METHODS AND PROCEDURES

3.1 Participants and Experimental Design

A sample of 38 premier division club level female Edmonton Rugby Union players between the ages of 18-34 years consented to be participants in this study. Four players per game were video recorded for the entire match from each of the 4 sub-categories of tight four, back row, inside backs and outside backs in order to attempt to get a complete representation of the larger groups of forwards (n=20) and backs (n=18). Two data sets are missing from the backs due to one camera and one research assistant malfunction.

Stratified random sampling of the consenting participants occurred prior to the random selection process. Playing positions are represented by numbers 1 through 15, which are visible on the back of each jersey. A number from each subgroup was randomly selected to determine which positions were to be filmed and the same process was used for heart rate participants. The scrumhalf, number 9, is an exception and was omitted from the random draw.

A specific orientation meeting was arranged with each of the 3 participating rugby clubs where an oral explanation of the study was presented and any questions answered. At this time any club member that was interested in volunteering was given the opportunity to fill out a consent form and obtain a participant information package and questionnaire which was approved by the Faculty of Physical Education and Recreation Research Ethics Board at the University of Alberta. Height (cm) and weight (kg) was collected using a tape measure and scale at the end of the meeting from the consenting participants.

3.2 Game Day Data Collection

Approximately 1 hour before kick off, the selected participants were given a heart rate monitor (Polar Electro Oy, Kempele, Finland) and instructed on appropriate fitting on the chest with a strap. The heart rate equipment was in place prior to warm up so that the individual's pre game routine was not disturbed and to become familiarized to the monitor. The heart rate receiver was programmed to start 15 minutes prior to the start time of the match. The actual start of the match, the half time break, the start of the 2nd half and end of game was recorded so that the heart rates could be properly matched if the game did not start exactly on schedule. Four research assistants were assigned to video record the selected backs or forwards and instructed to follow their designated player throughout warm up with their digital video camera in order to get accustom to tracking them amongst the entire team. The research assistants were specifically trained in following a subgroup of forwards or backs and only filmed that subgroup throughout the entire study.

3.3 Camera Locations

The cameras were located on the center line (50m line), 5m from the sideline so that the participant would be visible at any location on the field as was determined in the pilot study (Appendix E). The camera and tripod were elevated 2 meters above the playing surface on top of one layer of scaffolding so that the spectators, referee or other athletes would not impede visibility.

During the match the chosen participant was maintained in the middle of the view with approximately a 5 meter radius around them at all times. The researchers operating the video cameras (Sony GR-DVL9800, Panasonic PV-GS150, JVC GR-DVL520U) continued recording through all stoppages in play as well as during injury time. In the case of a substitution or injury, the researcher assistants continued filming the substituted player.

3.4 Time Motion Analysis

The participant's movement patterns were coded into 12 different activity categories with the use of Dartfish TeamPro software version 4.0.6.0 (Fribourg, Switzerland) by the principal researcher. The categories of locomotion were: standing, walking, jogging, striding and sprinting. Intensive exertion encompassed the physical contact or non-running movements such as ruck/maul/tackle, packing down, scrumming and lifting. Finally kicking, jumping and tackling were considered discrete activities. Standing, walking and jogging were considered low intensity rest activities by previously published literature and were maintained as such in this study (Duthie et al., 2005; Deutsch et al., 1998; Roberts et al., 2008; Deutsch et al., 2007). The following were considered high intensity activities also known as work: striding, sprinting, ruck/maul/tackle, packing down, scrumming and lifting. The discrete activities of kicking, jumping and tackling were recorded in frequency of occurrence throughout the match. Time spent kicking and jumping was not reported as it was very minimal and as a result had little influence on the physiology of the game. Total and mean duration, frequency as well as the percent time of each activity were measured as well as work and rest totals, intervals and ratios were calculated.

3.5 Heart Rate

The participant's heart rate was recorded and stored in the monitor every 5 seconds throughout the game and the data downloaded to computer after the match. Maximum heart rate was determined on a separate day by VO_{2max} treadmill laboratory test (Appendix B) to volitional exhaustion. In the event a higher heart rate was attained during match play it was used as the maximum heart rate. This allowed the calculation of the relative amount of time spent above and below a particular percentage of heart rate max. Match minimum heart rate, mean heart rates of both halves and whole match heart rate were also reported. Comparisons were made in all previously stated heart rate measurements between backs and forwards.

3.6 Definition of Movement Categories:

LOW INTENSITY / REST

1) **Standing:** no locomotor movement (Docherty et al., 1988; Duthie et al., 2005). This category also includes sitting or lying on the ground if the athlete is injured or winded (Deutsch et al., 2007).
2) **Walking:** slow locomotor movement in any direction without a flight phase (Duthie et al., 2005).

3) **Jogging:** locomotion with a flight phase, slow running with no particular haste and minimal arm swing where elbows stay within the body (Duthie et al., 2005; Deutsch et al., 2007).

HIGH INTENSITY / WORK

4) **Striding:** running with purpose, accelerating with an elongated stride and a more active arm swing, not at maximal effort (Docherty et al., 1988; Duthie et al., 2005; Deutsch et al., 2007).
5) **Sprinting:** running at maximum speed or full locomotor effort, full knee drive and full arm swing (Docherty et al., 1988; Duthie et al., 2005; Deutsch et al., 2007).

Intense non-running Exertion: Ruck, maul, tackle, pack down, scrum and lift.

6) **Ruck, Maul & Tackle:** When a ruck, maul or tackle action is executed, in all three cases the action begins when participant comes in purposeful contact with another player and ends with their detachment (Roberts et al., 2008).
7) **Pack down:** The movement starts when the body attains the coiled position and ends with the engagement of the scrum.
8) **Scrum:** The scrum starts when the two teams come together in contact (engagement) and has ended for the subject when they emerge and separate from the pack.

9) **Lifting:** The lifting action commences when the booster moves into a squatting position and ends the jumpers feet return to the ground. (Duthie et al., 2005; Deutsch et al., 2007)

Discrete Activities: Kick, jump and tackle.

10) **Kick:** Kicks were counted in any of the following forms: grubber kick, drop kick, punt or place kick.

11) **Jump:** The jump frequency was recorded. A jump consists of recoil of the legs with an upward driving force so that both feet leave the ground. (Duthie et al., 2005; Deutsch et al., 2007)

12) **Tackle:** The number of tackles made during a game was recorded. A tackle constitutes the subject taking the opposition completely to ground as the primary tackler.

3.7 Reliability

In order to establish intra-rater reliability, one full game (80min) from the forward and back positional groupings was coded on two different occasions by the principal investigator. The coefficient of correlation for intra-rater reliability was found to be r = 0.999 for both the forwards and the backs. Inter-rater reliability was established by the primary coder and an expert in the field coding two full games, one back and one forward position. The coefficient of correlation for inter-rater reliability was found to be r = 0.990 for forwards and r = 0.991 for backs.

3.8 Validity

The movement categories defined in this study were based on previously validated published work (Duthie et al., 2005; Deutsch et al., 1998; Docherty et al., 1988; Doutreloux et al., 2002; Deutsch et al., 2007; Roberts et al., 2008). The movement categories and their respective definitions most closely resemble Deutsch et al. (2007).

In order to establish a form of content validity of the movement categories, rugby coaches were asked to identify and rate the importance the movement patterns necessary to succeed in the sport in survey form. The coaches who agreed to participate in a content validity questionnaire (Appendix C) had a mean of 9.7 years of coaching experience; 3.9 years coaching women's premier club; and, a mean NCCP certification of level 2. Forwards and backs were treated separately. The results showed that the high intensity work categories were rated of highest importance and more specifically, static exertion activities for forwards and sprinting and tackling for backs.

3.9 Statistical Analysis

The recorded data was uploaded into and movement category information gathered by a Dartfish TeamPro time motion analysis software. This software encodes and interprets through keystrokes and records the time and sequence of events. The list of time coded events was then exported into a spreadsheet for further analysis.

Mean $\pm$ standard deviation for total and mean time and frequency of each activity were calculated for each of the movement categories in Excel XP 2002. Work and rest intervals were also calculated so that work to rest ratios could be determined.

Heart rate measures were reported as the relative time spent above and below 80 percent of maximum heart rate. Match minimum and maximum heart rate and the mean heart rate of both halves and the whole match were also reported.

A two stage testing process was used to compare the forwards and the backs in all variables. First a multivariate analysis of variance and Wilks' Lambda were employed to control for type 1 error. If a significant difference was found ($p<0.05$) stage two included a univariate test on only one variable at a time ignoring all others (Finn, 1974; Hummel & Sligo, 1971). A repeated-measures analysis of variance was used to compare forwards and backs mean heart rates for the 1st and 2nd halves. All significant differences reported were at alpha level of $p<0.05$. A Pearson's product moment coefficient of correlation was used to determine inter and intra rater reliability.

CHAPTER 4

RESULTS

4.1 Subject characteristics

The sample used in this study had a mean age of 24.1 years, 7.3 years experience playing rugby, 5.0 years experience playing premier club level and an average height and weight of 168.7cm and 73.4kg.

4.2 General Game Characteristics

The 10 matches that were investigated resulted in an 8-2 win/loss record (Table 1). The average game time temperature was 22.9 degrees Celsius. On average there were 35 points scored by the observed teams and 15 points scored against. During each match there was an average of 21 lineouts and 33 scrums during an average match length of 86 minutes and 35 seconds of actual play, injury time included.

Table 1. General game characteristics and results of the 10 matches investigated.

Game	Results	Score	Average Temp (C)	Lineouts (#)	Scrums (#)	Game Time (min:sec)
1	Lost	12 - 54	21.9	10	33	81:35
2	Won	22 - 12	19.6	28	37	93:48
3	Won	75 - 0	18.8	19	30	82:51
4	Won	25 - 5	25.1	22	35	93:19
5	Won	74 - 0	20.1	11	35	78:55
6	Won	39 - 29	33.5	19	17	87:33
7	Won	38 - 13	20.4	20	45	90:31
8	Won	38 - 20	19.4	24	31	85:19
9	Lost	12 - 15	25.5	22	36	89:39
10	Won	15 - 5	24.8	34	32	83:14

4.3 Time Motion Analysis

i) - Categories of Locomotion

Standing

There were no significant differences between forwards and backs in the frequency of occurrence, total or mean time spent standing.

Walking

Backs spent significantly more total and mean time walking than the forwards (Table 2 & 3).

Jogging

Forwards spent more total and mean time jogging than backs (Table 2 & 3) as well as were found to jog on more individual occasions than backs (Table 4).

Striding

The only difference between forwards and backs in the striding movement category was that the mean time striding was longer in duration for forwards (Table 3).

Sprinting

Forwards spent less time sprinting and had a lower total number of sprints in a match than backs (Table 2 & 4).

ii) Intensive Non-Running Exertion

Lift

The forwards were found to lift for more total time and more frequently than the backs during a match (Table 2 & 4).

Ruck/Maul/Tackle

Backs spent significantly less total time in physical contact rucking, mauling and tackling than forwards (Table 2). This would be in part due to the observed lower frequency of occurrence (Table 4).

Scrum/Pack Down

Forwards are the only group that are involved in scrumming therefore they spent significantly more time scrumming and had a higher frequency than the backs (table 2 & 4).

iii) Discrete Activities

Kick/Jump

There was no significant difference in the number of kicks that occurred per game and jump frequency was observed to be higher in the forwards (Table 4).

Tackle

There were no significant differences between any of the forwards and backs in the number of tackles made in a match.

Table 2. Total time (min:sec) spent in each movement category through out an entire match.

	Forwards (n=20)	Backs (n=18)
Stand	20:18 ± 4:06	19:00 ± 5:00
Walk	36:42 ± 4:24 [a]	51:00 ± 5:30 [a]
Jog	10:54 ± 3:00 [a]	7:24 ± 1:42 [a]
Stride	4:06 ± 1:36	3:30 ± 0:48
Sprint	1:42 ± 1:24 [a]	2:36 ± 0:54 [a]
Lift	0:18 ± 0:30 [a]	0 [a]
R/M/T	5:42 ± 1:42 [a]	2:12 ± 1:12 [a]
Pack Down	2:42 ± 1:42 [a]	0 [a]
Scrum	3:54 ± 0:54 [a]	0 [a]

[a] Significant difference between back and forward, $p<0.05$ (Appendix F).
Values are means ± standard deviation.

Table 3. Mean time (sec) spent in each movement category through out an entire match.

	Forwards (n=20)	Backs (n=18)
Stand	8.1 ± 1.7	7.1 ± 1.8
Walk	8.1 ± 0.9 [a]	11.0 ± 1.7 [a]
Jog	5.1 ± 1.0 [a]	3.8 ± 0.4 [a]
Stride	4.9 ± 0.9 [a]	4.1 ± 0.5 [a]
Sprint	3.9 ± 1.1	4.2 ± 0.6
Lift	1.5 ± 1.6 [a]	0 [a]
Ruck/Maul/Tackle	5.5 ± 0.7	5.2 ± 0.9
Pack Down	4.4 ± 2.2 [a]	0 [a]
Scrum	7.2 ± 1.2 [a]	0 [a]

[a] Significant difference between back and forward, $p<0.05$ (Appendix G).
Values are means ± standard deviation.

Table 4. Total frequency of the occurrence of each movement category during an entire match.

	Forwards (n=20)	Backs (n=18)
Stand	153 ± 29	164 ± 36
Walk	273 ± 35	283 ± 36
Jog	128 ± 19 [a]	114 ± 18 [a]
Stride	49 ± 15	52 ± 10
Sprint	25 ± 16 [a]	37 ± 12 [a]
Kick	1 ± 3	3 ± 5
Jump	6 ± 9 [a]	1 ± 2 [a]
Tackle	6 ± 3	5 ± 4
Lift	6 ± 9 [a]	0 [a]
Ruck/Maul/Tackle	61 ± 12 [a]	25 ± 11 [a]
Pack Down	32 ± 8 [a]	0 [a]
Scrum	33 ± 7 [a]	0 [a]

[a] Significant difference between back and forward, $p<0.05$ (Appendix H).
Values are means ± standard deviation.

4.4 Heart Rate Analysis

Forwards had a significantly higher average match heart rate than backs (Table 5). The forwards also spent more time above 80% of their heart rate max than the backs and the backs spent more time under 80% of their heart rate max compared to the forwards (Table 5). There was no significant difference in the treadmill or game maximum heart rate as well as the game minimum heart rate (Table 5). Forwards and backs repeated measure of 1st and 2nd half average heart rate showed no significant difference (Table 6, Appendix J).

Table 5. Heart rate measurements ($b \cdot min^{-1}$).

	Forwards (n=15)	**Backs (n=12)**
Tread MHR	198 ± 5	195 ± 8
Game MHR	195 ± 8	192 ± 9
Game Min HR	120 ± 13	111 ± 14
Game Ave.	173 ± 10 [a]	161 ± 10 [a]
80% MHR	160 ± 5	157 ± 7
% game > 80	81 ± 14 [a]	63 ± 20 [a]
% game < 80	19 ± 14 [a]	37 ± 20 [a]

[a] Significant difference between back and forward, $p<0.05$ (Appendix I). Values are means ± standard deviation. Treadmill maximal heart rate (Tread MHR), game maximal heart rate (Game MHR), game minimal heart rate (Game Min HR), whole game mean heart rate (Game Ave), 80% of maximal heart rate which was the highest overall heart rate attained on the treadmill or in the match (80% MHR), percent of game played above 80% of heart rate max (% game >80), percent of game played below 80% of heart rate max (% game <80).

Table 6. 1st and 2nd mean heart rate for forwards and backs (b · min^{-1}).

	Forwards (n=15)	Backs (n=12)
1st Half Average HR	176 ± 9	165 ± 11
2nd Half Average HR	171 ± 13	157 ± 11

Values are means ± standard deviation.

4.5 Work and Rest Intervals

A higher total work frequency was observed for the forwards when compared to the backs (Table 7, Figure 2). Forwards were also found to have a higher frequency in 5 of the 6 work interval categories: 4-8s, 8-12s, 12-16s, 16-20s and >20s (Table 7).

A higher total rest frequency was observed in the forwards when compared to the backs as well as more frequent rest durations of 0-20s and 20-40s. Backs on the other had a higher number of rest intervals of >100s in length (Table 7, Figure 3).

Total and mean work and rest calculations reported that forwards spend more time in high intensity work activities throughout a game and less time in low intensity rest activities than backs. As a result the forwards work-to-rest ratio for forwards was lower when compared to the backs (Table 8).

Table 7. Work and rest interval frequency.

	Forwards (n=20)	Backs (n=18)
WORK Frequency	132 ± 17 [a]	79 ± 15 [a]
0-4s	34 ± 9	31 ± 9
4-8s	37 ± 7 [a]	25 ± 6 [a]
8-12s	31 ± 9 [a]	13 ± 4 [a]
12-16s	18 ± 5 [a]	7 ± 3 [a]
16-20s	7 ± 6 [a]	2 ± 1 [a]
>20s	5 ± 5 [a]	1 ± 1 [a]
REST Frequency	134 ± 17 [a]	80 ± 16 [a]
0-20s	71 ± 17 [a]	27 ± 11 [a]
20-40s	31 ± 8 [a]	14 ± 7 [a]
40-60s	12 ± 5	11 ± 3
60-80s	7 ± 2	7 ± 4
80-100s	5 ± 2	5 ± 2
>100s	9 ± 3 [a]	16 ± 3 [a]

[a] Significant difference between back and forward, $p<0.05$ (Appendix K). Values are means ± standard deviation. Work and rest frequency headings represent whole match frequency totals.

Table 8. Work and rest variables.

	Forwards (n=20)	Backs (n=18)
Total work time (min)	18.4 ± 3.7 [a]	8.5 ± 2.0 [a]
Mean work (s)	8.4 ± 1.0 [a]	6.6 ± 2.0 [a]
Total rest time (min)	67.9 ± 5.0 [a]	77.4 ± 4.8 [a]
Mean rest (s)	31.1 ± 5.5 [a]	60.1 ± 12.5 [a]
Mean work:rest ratio (1:x)	3.8 ± 0.9 [a]	9.5 ± 2.4 [a]

[a] Significant difference between back and forward, $p<0.05$ (Appendix L).
Values are means ± standard deviation.

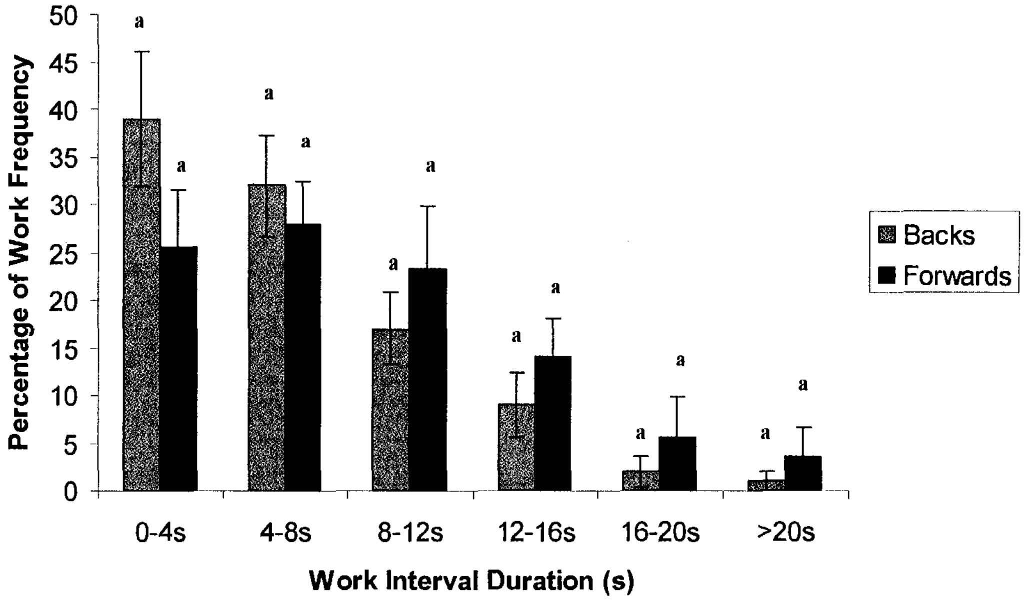

Figure 2. Frequency distribution (mean ± sd) of work intervals for both backs and forwards throughout an entire match. The percentage of work frequency represents the total number of work occurrences in an interval divided by the number of total match work occurrences. [a] Significant difference between back and forward, $p<0.05$ (Appendix M).

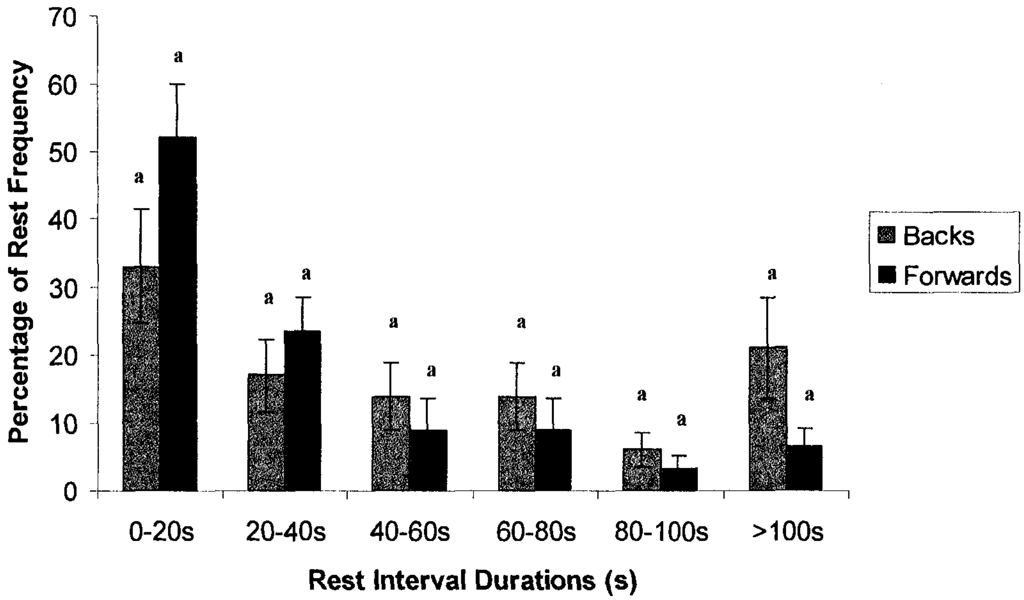

Figure 3. Frequency distribution (mean ± sd) of rest intervals for both backs and forwards throughout an entire match. The percentage of rest frequency represents the total number of rest occurrences in an interval divided by the number of total match rest occurrences. [a] Significant difference between back and forward, $p<0.05$ (Appendix M).

CHAPTER 5

GENERAL DISCUSSION & CONCLUSIONS

5.1 Discussion

The purpose of this study was to use time motion analysis and heart rate response to quantify movement patterns to assess the physical demands of female premier club rugby union athletes. The findings of this study did not support the hypothesis that there would be no significant difference in the movement categories, work and rest intervals or heart rate measurements between the forwards and the backs. Significant differences between positional roles in women's rugby union were observed.

5.2 Time Motion Analysis

Forwards spend significantly more time in intensive non-running exertion activities than backs. This would be a direct result of their positional role in gaining and maintaining possession of the ball. Not only were forwards solely involved in lineouts and scrums but they also spend 4% more total match time in rucks and mauls. In addition forwards spend more time jogging whereas back spend more time walking. It is possible that the positional requirement of continually following the ball for forwards is responsible for the greater amount of time spent jogging (Deutsch et al., 2007). On the other hand backs are required to maintain proper spatial positioning in the back line when the ball changes field location while anticipating involvement and as a result may need to walk more (Deutsch et al., 2007). Furthermore backs sprint for longer durations and more often throughout a match.

This supports their positional role requirement of ball carriers where gaining territory and scoring are of primary importance.

5.3 Work and Rest Intervals

Forwards displayed a very similar distribution across the first 3 work intervals (0-4s, 4-8s, 8-12s) for a combined total of 77% of the total work interval frequency while the rest interval category of 0-20s encompassed over half of the total match rest frequency (53%). These results would indicate that forwards ATP-PC system plays an important role as the majority of work bouts are under 12 seconds. However with over half of the rest intervals lasting less than 20 seconds only partial replenishment of the ATP-PC stores can take place. As a result of the incomplete recovery of ATP-PC system, a heavier reliance on the anaerobic glycolytic pathways would likely contribute more extensively to the match performance of a forward.

Backs tended to participate mostly in work intervals of 0-4s and 4-8s range where percent of total match frequency was 39% and 31% respectively. Due to the fact that 66% of the rest intervals for backs were greater than 20s, in many instances throughout the game backs ATP-PC stores would have had time to at least partially if not fully recover. However, 34% of the rest intervals were in the 0-20s category which may indicate that at times during the match there was an increased reliance on anaerobic glycolysis though not to the same extent as forwards.

5.4 Heart Rate

Forwards had significantly higher whole game mean heart rate which indicates an overall higher demand for oxygen to perform work when compared to backs. The percentage of total match time above 80% of the forwards maximum heart rate supports this as 81% of the game time was spent above this 80% maximum heart rate threshold versus 63% for backs. Deutsch et al. (1998) found similar results where props, locks and backrow forwards spent a greater amount of time in the high intensity heart rate zone (85-95% HR_{max}) compared to backs. The higher percent game time spent in the below 80% maximum heart rate category is most likely due to the intermittent activity nature of their position (Deutsch et al., 1998). It has been found that isometric activities require more work and as a result produce higher heart rates (Patterson 1985 as seen in Deutsch 1998). Therefore, the increased times that forwards spend in intensive non-running exertion as well as the shorter average rest periods may largely be responsible for the higher average heart rate throughout a match.

5.5 Limitations

These results are specific to the investigated population of women's Alberta premier club rugby union during the 2006 season. In addition, time motion analysis is restricted in its ability to assess activities that involve complex movements, technical skill, decision making ability, strategy or tactics.

5.6 Conclusions

This is the first study to report on the physiological demands of women's rugby union premier club match play. The current data indicates that rugby union is a complex game that is composed of intermittent high intensity work periods, where the aerobic system is necessary for all positions for quick and efficient recovery between work efforts. Forwards spent more time in intense non running activities and backs spent more time in high intensity running with longer recovery periods than forwards. These observations are in support of the current men's rugby union time motion analysis literature (Deutsch et al., 1998; Docherty et al., 1988; Doutreloux et al., 2002; McLean, 1992; Rienzi et al., 1999; Deutsch et al., 2005; Deutsch et al., 2007; Roberts et al., 2008).

5.7 Practical Applications

In terms of practical applications, the forwards greater involvement in intense non-running exertion activities suggests a considerable reliance on anaerobic glycolysis for energy and muscular strength and power to support these movement patterns. Training should involve position specific work activities of a contact nature with work and rest periods that are aimed at incurring stress on anaerobic glycolytic metabolism. Because many of the non-running exertion activities for forwards also rely on considerable muscular strength and power, future off-season conditioning resistance training programs should be specific to the major muscle groups that are utilized in these non-running exertion activities (i.e. ruck, maul, tackle, pack down, scrum and lift). The backs longer rest periods and increased involvement in high intensity running activity indicates that training should focus on development of speed in a form of intervals with adequate rest for recovery to enhance both the capacity and activity of the ATP-PC energy system. Anaerobic glycolytic metabolism should also be trained to a certain degree for backs as complete recovery does not always occur during a match. Because a solid aerobic based is important in the recovery of the ATP-PC and anaerobic glycolytic systems, both forwards and backs would require development of this system as part of the overall periodized training schedule.

Although numerous studies have been previously published using time motion analysis techniques for men's rugby union, this study provided new knowledge that increases the current understanding of positional physiological demands specific to women who play rugby. The findings of this study will allow athletes and coaches alike to create position specific training sessions as well as strength and conditioning programs.

5.8 Future Directions

Future research should attempt to investigate a more elite level of play such as international women's teams. Due to the small sample size, the individual participants on the national team could be evaluated multiple times which would provide a more accurate depiction of positional match physiology. The forward and back grouping categories could also be further broken down to the four positional subgroups used in the men's literature. A 1^{st} and 2^{nd} half comparison of all variables would be an interesting study to determine the possible effects of fatigue. The physiology of the positional requirements needs to be considered when interpreting fitness testing results. Therefore a research study on women's rugby analyzing both the positional physiological demands as well as the anthropometric and physiological characteristics would be beneficial. Future research should endeavour to run longitudinal studies on the effects of specific training programs with creatine phosphate supplementation to determine if the ATP-PC recovery rates could be enhanced. Furthermore, as the technology in the field advances it may even be possible to evaluate the specific effects of tactics and team strategies on the positional physiological requirements.

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APPENDIX A

Women's Premier Division Fixtures 2006

Day	Date	Team 1	Team 2	Div	Location	Time
Saturday	03-Jun	Druids	CCIAC	AWP	ERP	14:00
***Saturday**	**10-Jun**	**L-T's**	**CCIAC**	**AWP**	**ERP**	**1:45**
Wednesday	14-Jun	St.Albert	Pirates	AWP	SA	19:00
***Thursday**	**15-Jun**	**Druids**	**Clanswomen**	**AWP**	**SD**	**19:00**
Saturday	24-Jun	Pirates	Lep-Tigers	AWP	PIR	14:00
Wednesday	28-Jun	Druids	St. Albert	AWP	SD	19:00
Wednesday	12-Jul	Rockers	Pirates	AWP	ERP	19:00
Saturday	22-Jul	Pirates	Druids	AWP	ERP	14:00
Saturday	29-Jul	L-T's	CCIAC	AWP	ERP	14:00
Saturday	12-Aug	Rockers	Lep-Tigers	AWP	ERP	14:00
Saturday	26-Aug	L-T's	CCIAC	AWP	ERP	14:00
Saturday	09-Sep	Rockers	CCIAC	AWP	CRP	14:00

*** Matches where video was not taken but heart was measured.**

APPENDIX B

VO_{2max} Treadmill Laboratory Testing Protocol

The VO_{2max} test consisted of a continuous graded running treadmill exercise until volitional exhaustion. Warm up included five minutes on the treadmill at a jogging pace selected by the subject follow by five minutes of stretching. First a heart rate monitor was place around the subjects' chest (Polar Electro, Finland) and then they were hooked up to a Hans Rudolf Valve assembly.

Speed was increased by 0.5 km/hr every two minutes until respiratory exchange ratio neared 1.0 and then speed was maintained and grade was increased by 2% every minute until volitional exhaustion. The expired air was analyzed by a metabolic cart (Horizon, sensor medics, CA). A pre and post exercise test calibration was conducted with known gases as well as volume test once a day. Two of the three following criteria needed to be met in order to ensure maximal heart rate was obtained: Volitional exhaustion of subject, RER >1.1 or a peak and plateau of the VO_{2max} value.

APPENDIX C

UNIVERSITY OF ALBERTA Faculty of Physical Education and Recreation

E488 Van Vliet Centre
Edmonton, Alberta, Canada T6G 2H9

Coaches Survey

Physiological demands of women's rugby union match play: Time motion analysis and heart rate response.

Dear Coach/technical expert,

We are seeking your feedback concerning the importance of specific movement patterns in the overall success of the female rugby athlete as a part of the research study concerning the physiological demands of women's rugby. The major benefit of your participation in this study will be to help the researchers create an accurate set of movement pattern categories with which female rugby athletes' movements will be analyzed. The following list of male rugby movement patterns have been found in the literature: standing, walking, jogging, striding, sprinting, utility movements, static exertion, tackling, lifting and jumping. The importance of specific movement patterns for **FORWARDS (#1-8)** will be analyzed on the first page and **BACKS (#10-15)** on the second page.

Thank you for considering completing this three part survey. All completed surveys can be faxed to the University of Alberta **492-2364 attention Jody Virr.** Please make sure all **3 pages** are faxed together. If it is your wish to email your response please make sure you mark your choice on the survey scale by changing its **colour** and send it to jvirr@ualberta.ca. If you have any questions or concerns about this research project please do not hesitate to contact Jody Virr by email at jvirr@ualberta.ca.

Thank you,

JVirr Dan Syrotuik

Jody Virr, M.Sc. Student **Dan Syrotuik, Ph.D.**

PART ONE - COACHING HISTORY:

Name (optional):

Total years of coaching experience (men or women):

Number of years coaching women's 1st or Premier division:

Highest level coached:

NCCP Coaching Certification:

PART TWO – FORWARDS

On a scale from 1-5 please rate the importance of each movement pattern in the overall success of a female **FORWARD** athlete. Please circle the most appropriate number.

	1	2	3	4	5
1. Standing	Not at all	Seldom	Sometimes	Often	Always
2. Walking	Not at all	Seldom	Sometimes	Often	Always
3. Jogging	Not at all	Seldom	Sometimes	Often	Always
4. Striding (more arm swing and elongated stride then jogging)	Not at all	Seldom	Sometimes	Often	Always
5. Sprinting	Not at all	Seldom	Sometimes	Often	Always
6. Utility Movements (Backward, lateral movement and kicking)	Not at all	Seldom	Sometimes	Often	Always
7. Static Exertion (Scrum, ruck, maul)	Not at all	Seldom	Sometimes	Often	Always
8. Tackling	Not at all	Seldom	Sometimes	Often	Always
9. Lifting	Not at all	Seldom	Sometimes	Often	Always
10. Jumping	Not at all	Seldom	Sometimes	Often	Always
11 (Other?)	Not at all	Seldom	Sometimes	Often	Always

PART THREE – BACKS

On a scale from 1-5 please rate the importance of each movement pattern in the overall success of a female **BACK** athlete. Please circle the most appropriate number.

1. Standing	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
2. Walking	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
3. Jogging	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
4. Striding (more arm swing and elongated stride then jogging)	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
5. Sprinting	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
6. Utility Movements (Backward, lateral movement and kicking)	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
7. Static Exertion (Scrum, ruck, maul)	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
8. Tackling	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
9. Lifting	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
10. Jumping	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always
11 (Other?)	**1** Not at all	**2** Seldom	**3** Sometimes	**4** Often	**5** Always

APPENDIX D

Women's Premier Division Year End Standings

2005 year end standings	Points	Place
*Lep/Tigers	45	1st
*Rockers	38	2nd
CCIAC	37	3rd
*Druids	17	4th
Lethbridge	15	5th
Saracens	-9	6th

2006 year end standings	Points	Place
CCIAC	34	1st
*Lep/Tigers	27	2nd
*Rockers	27	3rd
Lethbridge	25	4th
*Druids	16	5th
Clanswomen	10	6th
*Pirates	7	7th
St. Albert	0	8th

* Teams that were part of the study.

APPENDIX E

Pilot Study

A pilot study was conducted to allow preliminary observation and assessment of both the practicality of the proposed methods and analysis techniques as well as to gain practice and experience in order to improve future reliability. Observations from pilot study were as follows. Arm bands on athletes were not visible through the view finder therefore it was best to practice filming participants during warm up to learn their running style. Researchers found it easiest to film participants of the same subgroup due to the similar positional movement. The VHS-C cameras used in the pilot study needed to be converted from analog to digital and the quality of the video was not optimal, therefore digital cameras were utilized for the study. The distance between the field sideline and the scaffolding was optimal at 5m as any closer made the near corners of the field impossible to see and farther away allowed tall match spectators to obstruct the view. Battery lengths were tested and a battery pack purchased to ensure full game video. Video analysis was practiced in order to get used to discerning all movement categories. Definitions of the movement categories were further developed and refined to include a few more categories (pack down, ruck/maul/tackle, lift, kick and jump). The utility category from Deutsch et al. (2005) was eliminated due to the incomplete definition that made it impossible to analyze accurately.

APPENDIX F

General Linear Model – Total Time

Between-Subjects Factors

		N
VAR00001	1	18
	2	20

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
VAR00001	Pillai's Trace	.944	52.535[a]	9.000	28.000	.000	.944
	Wilks' Lambda	**.056**	**52.535[a]**	**9.000**	**28.000**	**.000**	**.944**
	Hotelling's Trace	16.886	52.535[a]	9.000	28.000	.000	.944
	Roy's Largest Root	16.886	52.535[a]	9.000	28.000	.000	.944

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
VAR00001	**Lift**	**3085.952**	**1**	**3085.952**	**7.490**	**.010**	**.172**
	Jog	**439060.818**	**1**	**439060.818**	**19.725**	**.000**	**.354**
	Pack Down	**201060.804**	**1**	**201060.804**	**52.818**	**.000**	**.595**
	R/M/T	**406034.994**	**1**	**406034.994**	**65.560**	**.000**	**.646**
	Scrum	**527263.171**	**1**	**527263.171**	**309.112**	**.000**	**.896**
	Sprint	**26191.271**	**1**	**26191.271**	**5.336**	**.027**	**.129**
	Stand	56156.644	1	56156.644	.768	.386	.021
	Stride	11689.389	1	11689.389	2.029	.163	.053
	Walk	**7050827.576**	**1**	**7050827.57**	**80.190**	**.000**	**.690**

APPENDIX G

General Linear Model – Mean Time

Between-Subjects Factors

		N
VAR00001	1	18
	2	20

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
VAR00001	Pillai's Trace	.966	87.915[a]	9.000	28.000	.000	.966
	Wilks' Lambda	**.034**	**87.915[a]**	**9.000**	**28.000**	**.000**	**.966**
	Hotelling's Trace	28.258	87.915[a]	9.000	28.000	.000	.966
	Roy's Largest Root	28.258	87.915[a]	9.000	28.000	.000	.966

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
VAR00001	**Lift**	**21.946**	**1**	**21.946**	**16.075**	**.000**	**.309**
	Jog	**14.994**	**1**	**14.994**	**24.672**	**.000**	**.407**
	Pack Down	**187.350**	**1**	**187.350**	**75.201**	**.000**	**.676**
	R/M/T	1.114	1	1.114	1.565	.219	.042
	Scrum	**489.616**	**1**	**489.616**	**618.472**	**.000**	**.945**
	Sprint	1.360	1	1.360	1.788	.190	.047
	Stand	9.587	1	9.587	3.131	.085	.080
	Stride	**6.661**	**1**	**6.661**	**12.037**	**.001**	**.251**
	Walk	**78.415**	**1**	**78.415**	**42.583**	**.000**	**.542**

APPENDIX H

General Linear Model – Frequency

Between-Subjects Factors

		N
VAR00001	1	18
	2	20

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
VAR00001	Pillai's Trace	.950	39.987[a]	12.000	25.000	.000	.950
	Wilks' Lambda	**.050**	**39.987[a]**	**12.000**	**25.000**	**.000**	**.950**
	Hotelling's Trace	19.194	39.987[a]	12.000	25.000	.000	.950
	Roy's Largest Root	19.194	39.987[a]	12.000	25.000	.000	.950

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
VAR00001	**Lift**	**313.224**	**1**	**313.224**	**8.114**	**.007**	**.184**
	Jog	**1811.439**	**1**	**1811.439**	**5.056**	**.031**	**.123**
	Pack Down	**9550.066**	**1**	**9550.066**	**305.942**	**.000**	**.895**
	R/M/T	**12521.619**	**1**	**12521.619**	**94.322**	**.000**	**.724**
	Scrum	**10348.129**	**1**	**10348.129**	**427.731**	**.000**	**.922**
	Sprint	**1357.902**	**1**	**1357.902**	**6.955**	**.012**	**.162**
	Stand	1081.266	1	1081.266	1.024	.318	.028
	Stride	60.268	1	60.268	.358	.554	.010
	Walk	9.474	1	9.474	.686	.413	.019

APPENDIX I

General Linear Model – Heart Rate Measurements

Between-Subjects Factors

		N
var0001	1	12
	2	15

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
VAR00001	Pillai's Trace	.482	3.097[a]	6.000	20.000	.026	.482
	Wilks' Lambda	**.518**	**3.097[a]**	**6.000**	**20.000**	**.026**	**.482**
	Hotelling's Trace	.929	3.097[a]	6.000	20.000	.026	.482
	Roy's Largest Root	.929	3.097[a]	6.000	20.000	.026	.482

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
VAR00001	Tread MHR	91.267	1	91.267	2.087	.161	.077
	Game MHR	63.380	1	63.380	.897	.353	.035
	Game min HR	558.150	1	558.150	3.160	.088	.112
	Game Ave.	**892.381**	**1**	**892.381**	**9.555**	**.005**	**.277**
	80% MHR	46.464	1	46.464	1.384	.250	.052
	% game >80	**2156.242**	**1**	**2156.242**	**7.721**	**.010**	**.236**
	% game <80	**2156.242**	**1**	**2156.242**	**7.721**	**.010**	**.236**

APPENDIX J

General Linear Model – 1^{st} and 2^{nd} half average heart rate

Descriptive Statistics

	VAR00001	Mean	Std. Deviation	N
1^{st} Half	1-Backs	165.0742	10.55824	12
	2- Forwards	176.4380	9.45801	15
	Total	171.3874	11.33325	27
2^{nd} Half	1-Backs	157.4792	11.12505	12
	2- Forwards	170.8647	12.90006	15
	Total	164.9156	13.70804	27

APPENDIX K

General Linear Model – Work Rest Interval

Between-Subjects Factors

		N
VAR00001	1	18
	2	20

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
VAR00001	Pillai's Trace	.898	18.279[a]	12.000	25.000	.000	.898
	Wilks' Lambda	**.102**	**18.279[a]**	**12.000**	**25.000**	**.000**	**.898**
	Hotelling's Trace	8.774	18.279[a]	12.000	25.000	.000	.898
	Roy's Largest Root	8.774	18.279[a]	12.000	25.000	.000	.898

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
VAR00001	**Work Frequency**	**26477.853**	**1**	**26477.853**	**98.120**	**.000**	**.732**
	0-4s	69.348	1	69.348	.838	.366	.023
	4-8s	**1346.584**	**1**	**1346.584**	**30.011**	**.000**	**.455**
	8-12s	**2949.408**	**1**	**2949.408**	**58.496**	**.000**	**.619**
	12-16s	**1222.814**	**1**	**1222.814**	**76.224**	**.000**	**.679**
	16-20s	**281.392**	**1**	**281.392**	**12.972**	**.001**	**.265**
	>20s	**135.603**	**1**	**135.603**	**11.694**	**.002**	**.245**
	Rest Frequency	**26891.257**	**1**	**26891.257**	**98.985**	**.000**	**.733**
	0-20s	**17816.853**	**1**	**17816.853**	**88.079**	**.000**	**.710**
	20-40s	**2819.013**	**1**	**2819.013**	**52.318**	**.000**	**.592**
	40-60s	8.057	1	8.057	.452	.506	.012
	60-80s	2.213	1	2.213	.235	.631	.006
	80-100s	1.871	1	1.871	.351	.557	.010
	>100s	**509.474**	**1**	**509.474**	**52.179**	**.000**	**.592**

APPENDIX L

General Linear Model – Work Rest Variables

Between-Subjects Factors

		N
VAR00001	1	18
	2	20

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
VAR00001	Pillai's Trace	.814	27.973[a]	5.000	32.000	.000	.814
	Wilks' Lambda	**.186**	**27.973[a]**	**5.000**	**32.000**	**.000**	**.814**
	Hotelling's Trace	4.371	27.973[a]	5.000	32.000	.000	.814
	Roy's Largest Root	4.371	27.973[a]	5.000	32.000	.000	.814

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
VAR00001	**Total Work**	**3407716.368**	**1**	**3407716.368**	**104.438**	**.000**	**.744**
	Mean Work	**28.390**	**1**	**28.390**	**11.970**	**.001**	**.250**
	Total Rest	**3091310.359**	**1**	**3091310.359**	**35.418**	**.000**	**.496**
	Mean Rest	**7991.808**	**1**	**7991.808**	**88.287**	**.000**	**.710**
	Mean work:rest (1:x)	**313.042**	**1**	**313.042**	**95.630**	**.000**	**.727**

APPENDIX M

General Linear Model – % Interval Frequency

Between-Subjects Factors

		N
VAR00001	1	18
	2	20

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
VAR00001	Pillai's Trace	.866	15.251[a]	11.000	26.000	.000	.866
	Wilks' Lambda	**.134**	**15.251[a]**	**11.000**	**26.000**	**.000**	**.866**
	Hotelling's Trace	6.452	15.251[a]	11.000	26.000	.000	.866
	Roy's Largest Root	6.452	15.251[a]	11.000	26.000	.000	.866

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
VAR00001	**0-4s**	**1720.616**	**1**	**1720.616**	**40.452**	**.000**	**.529**
	4-8s	**134.054**	**1**	**134.054**	**5.565**	**.024**	**.134**
	8-12s	**431.432**	**1**	**431.432**	**14.946**	**.000**	**.293**
	12-16s	**256.004**	**1**	**256.004**	**17.794**	**.000**	**.331**
	16-20s	**91.336**	**1**	**91.336**	**8.197**	**.007**	**.185**
	>20s	**45.345**	**1**	**45.345**	**8.077**	**.007**	**.183**
	0-20s	**3510.389**	**1**	**3510.389**	**52.910**	**.000**	**.595**
	20-40s	**382.471**	**1**	**382.471**	**13.782**	**.001**	**.277**
	40-60s	**217.416**	**1**	**217.416**	**10.026**	**.003**	**.218**
	60-80s	**217.416**	**1**	**217.416**	**10.026**	**.003**	**.218**
	80-100s	**69.433**	**1**	**69.433**	**14.153**	**.001**	**.282**
	>100s	**1973.113**	**1**	**1973.113**	**65.215**	**.000**	**.644**