Observed versus Expected Match-Running Outputs of International Female Rugby Sevens Players

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Abstract

Women's rugby sevens is a new and emerging sport with limited knowledge, specifically on international female match-running outputs. It is a rare opportunity to conduct research on elite athletes, and even more so for an emerging women's sport. The overall aim of this thesis is to establish and compare observed international female rugby sevens players' match-running outputs versus theoretical expected match-running outputs (elite male players and an established sport, football). Another unknown aspect of the women's rugby sevens game is how fatigue affects performance. The thesis also determines differences in match-running outputs of international female rugby sevens players from half-to-half, game-to-game and tournament-to-tournament.

Global Positioning System (GPS) units worn on the players' backs were used to collect data from 18 female rugby sevens players across 15 matches and 19 female football players across four matches. Reasons for the gaps found in match-running outputs and aspects that could be improved for optimal elite performance in female rugby sevens were explored. The match-running output measures included low-to-moderate speed running (LMSR <16.5 km), high speed running (HSR >16.6 km), sprints (>21 km) and total distance (TD). These speed thresholds represent previously used zones in rugby sevens match analysis, as well as recommended zones for female sport settings (VX View software).

When compared with the expected match-running output measures, male and female rugby sevens players exhibited a large sex performance gap with male players recording more metres across all four measures, LMSR 64.8% ($p<0.01$), HSR 95.9% ($p<0.01$), TD 69.3% ($p<0.01$) and sprints 100% ($p<0.01$). Female football players and male football players demonstrated an unexpected sex performance gap in HSR of 152.3% ($p<0.01$), with male players performing more HSR metres. There was a smaller gap in TD 25.3% ($p<0.01$) and sprints 52.9% ($p<0.01$) and within the established performance gap for LMSR 2.3% ($p = 0.28$) between male and female footballers, again with male players recording more metres.

There were no significant decreases in match-running outputs for female rugby sevens players from 1st half to 2nd half. However, female football players showed a significant decrease in match-running output in LMSR ($p<0.01$), TD ($p<0.01$) and sprints ($p<0.01$) from 1st half to 2nd half. There were significant differences in match-running output in LMSR ($p<0.01$) for female rugby sevens players, specifically with an increase between tournaments 2 and 3 ($p<0.05$) and tournaments 1 and 3 ($p<0.05$). There were also significant differences in the number of sprints performed ($p<0.01$), with an increase between tournaments 1 and 2 ($p<0.05$), and a decrease between tournaments 2 and 3 ($p<0.05$), and a decrease between games 7 and 11. There were no significant differences in match-running outputs for female football players from game to game.

Overall, the findings from this thesis contribute to the limited knowledge on women's rugby sevens, specifically observing international female match-running outputs. The findings suggest that international female rugby sevens players have significant room to improve overall match-running outputs, aligning more closely with the expected sex performance gap (5-12%) and the established elite sport of football.

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Chapter 1

INTRODUCTION

1.0 Background of Problem

Rugby organisations and nations around the world have recently committed to investing in rugby sevens, and the women's game in particular (Chu et al, 2003). As investment in rugby sevens grows so does the necessity for relative and specific information about the game. Rugby sevens is a high-intensity short-intermittent sport, with a complex nature that demands players have well-developed overall physical fitness qualities, an ability to perform technical skills and tactical decision-making at an elite level (Meir, 2012). Despite the recent investment in women's rugby sevens it is still classed as an emerging sport, and many countries lack direct player development pathways from grassroots through to an international level (Goodale et al, 2016). The missing knowledge that this thesis seeks to provide has the potential to assist with player development and performance by aiding coaching and support staff with a rare insight to international level athlete performance.

There is a known physiological difference in performance levels between the best male and best female athletes (Muller, 2016; Caplan & Parent, 2017). However, as there is no set elite performance benchmark for rugby sevens or field-based team sports, establishing a benchmark would help determine expected performance measures for women's rugby sevens. This thesis derives an elite performance benchmark between sexes from past literature and various sports to assist in establishing expected match-running outputs of international female rugby sevens players. Subjecting female athletes to training programs for males may be inappropriate and could be physically damaging to female athletes, which is why greater research into female rugby sevens is needed (Myer, Ford & Hewett, 2004).

1.1 Problem and Motivation for the Study

This thesis looks to determine the observed match-running outputs of international female rugby sevens' players versus expected performance. While the demands on rugby sevens players have been documented (Goodale et al, 2016; Ross, Gill & Cronin, 2015b; Clarke, Anson & Pyne, 2014; Clarke et al, 2014; Higham et al, 2013; Suarez-Arrones et al, 2012; Rienzi, Reilly & Malkin, 1999) the available data is predominantly on male players with limited data on the physical characteristics and demands for female players. Only one study has investigated the differences between rugby sevens players (Ross, Gill & Cronin, 2015a/b) of different playing standards (international and provincial level). None of the studies documented have investigated the differences between international-level female and male players. International level is referred to as the 'elite' level and may also be referred to as 'professional'. Both 'elite' and 'professional' imply certain standards of training and off-field management (further defined throughout the thesis) which allow athletes optimal sporting development.

1.2 Outline Purpose and Specific Objectives

The primary purpose of this study is to determine the match-running outputs of current international female rugby sevens players to contextualise against expected match-running outputs. The expected match-running outputs will be estimated from international male rugby sevens match-running outputs by applying a percentage difference based on existing research data and other information. The known and quantified physiological difference in performance levels between male and female athletes, as mentioned briefly, will be the percentage difference used to judge expected match-running outputs for female rugby sevens players. Further discussed in the literature review, track and field athletics will be included in this study to identify a true elite sex performance gap, the thesis will then incorporate elite football as an established team-based field sport, which relies on multiple athletes for peak performance as does rugby sevens. Identifying the sex gap between elite footballers creates the opportunity for comparison of the sex gap between male and female rugby seven's players to that of an established sport played at an elite level.

There are multiple studies on men's rugby sevens (Ross, Gill, Cronin, 2015a; Granateli et al, 2014; Elloumi et al, 2012), men's football (Barte et al, 2017; Djaoui et al, 2017; Carling et al, 2018; Nedelec et al, 2012; Mohr, Krustrup & Bangsbo, 2005) and women's football (Krustrup et al, 2010; Mohr et al, 2008) that illustrate when elite players match-running outputs decrease due to fatigue and the process required to recover from fatigue (Carling & Dupont, 2011). However, there are no studies to reflect these patterns of fatigue for women's rugby sevens. Maintaining higher performance from half-to-half, match-to-match and across tournaments shows elite training adherence, an elite level of fitness, fatigue resistance and recovery (Austruy, 2016). Therefore, this thesis also looks to determine where a difference in match-running outputs occurs for women's rugby sevens through the investigation of 1st half vs. 2nd half data, game-to-game data and tournament-to-tournament data.

In order to assess observed and expected match-running outputs of female rugby sevens players and specific difference in match-running outputs during a game and across a tournament/s, specific objectives of the current study include:

- Determine characteristics/physical demands of rugby sevens.
- Use football as a comparable sport to determine differences in match-running outputs between sexes. Use athletic records for this purpose as well.
- Establish existing match-running outputs of male rugby sevens players and male footballers for comparison against female rugby sevens and football players (collected data).
- Test match-running outputs of selected elite female rugby sevens players and elite female footballers.
- Compare female footballers' data to existing match-running output data of male footballers to determine sex differences in performance levels.
- Compare female rugby sevens players data to existing match-running output data of male players to determine current differences in match-running outputs.

- Determine the significance of the difference in match-running outputs between sexes presented in the results.
- Determine the significance of the difference in match-running outputs between the 1st half and 2nd half of a game for female rugby sevens players.
- Determine the significance of the difference in match-running outputs between the 1st half and 2nd half of a game for female football players.
- Determine the significance of the difference in match-running outputs between games within a tournament and across tournaments for female rugby sevens players.
- Determine the significance of the difference in match-running outputs between games for female rugby sevens players.

The female data collected and the aspects above are important for the purpose of comparison against current literature on elite male rugby sevens players and elite male football players to establish the differences between sexes for both sports and reflect the current sporting level.

1.3 Structure of the Thesis

This thesis will be presented in six chapters. Chapter 1 will provide an initial introduction of the topic, outline the purpose and list specific objectives. Chapter 2 will provide a succinct review of rugby sevens and its history, physiological differences between males and females, match demands and analysis of rugby sevens and, key physical fitness requirements of rugby sevens and how fatigue affects the human body and elite athlete performance. Other sports, such as track-and-field athletics and football (soccer) are considered and discussed throughout the thesis due to the lack of specific research on female rugby sevens. These sports are relevant to the thesis as there are specific aspects of those sports that directly transfer to the female rugby sevens game. Track-and-field world records are considered to be a reliable way to assess athletic performance improvements (Lippi et al, 2008). Despite the total duration of a rugby sevens (14 min) match and a football (90 min) match are different, football as an established team-based sport gives a basis for distance and duration aspects of team-based field sports, using metres per minute and/or number of sprints per minute for cross comparisons. Using these other sports as benchmarks can highlight needed improvements in specific game characteristics and differences between male and female athletes.

Elite base figures for speed (Majumdar & Robergs, 2011), overall match-running outputs (total distance, low speed and high speed running) (Majumdar & Robergs, 2011; IAAF, 2016a/b & IWF, 2016a/b) and aerobic endurance (IAAF, 2016a/b) will be established throughout this thesis for the purpose of comparison between elite male and female rugby sevens' players. It is important to demonstrate the progression of ultimate human capacities, as amateur and/or lower-level data cannot be extrapolated to absolute human performance (Berthelot et al, 2015). Therefore this study will not examine or compare sub-elite athletes to elite athletes, as the study's focus is to examine the sex performance gap in order to identify areas of improvement for elite female rugby sevens players.

Chapter 3 will cover methodology, specifically the experimental approach, participants, equipment and logistics, data collection and statistical analysis. Chapter 4 will provide the results of the testing conducted on elite female rugby sevens players and elite female footballers. Chapter 5 will discuss the rugby sevens and football results, possible reasons for the results, the sex performance gap between their male counterparts along with comparisons between sports. Possible reasons for any significant differences in match-running outputs between halves, games and tournaments for female rugby sevens players and female football players will also be discussed. Chapter 6 will discuss the practical applications, limitations, further research suggestions and concluding thoughts.

Chapter 2

LITERATURE REVIEW

2.0 Introduction

While the primary focus of this review is the sport of elite female rugby sevens, due to limited literature on the game, in aspects of specific match demands, other related sports including rugby union, association football (soccer) and track and field athletics, have been included to further substantiate conclusions. This literature review discusses the history of rugby sevens, specific rules and regulations, the Olympics and the history of football. Also included are elite male and female physiological differences contributing to overall sporting performance.

The literature review defines contributing factors to expected differences between male and female rugby sevens players, and also highlights possible factors that can be improved to reduce the observed versus expected differences. Establishing current elite sporting performance of male and female athletes sets a bench-mark for expected performance of elite female rugby sevens players based on the current performance of their elite male counterparts. The review also considers techniques of data collection and analysis, critiquing and justifying the inclusion and exclusion of certain studies.

2.1 Rugby Sevens

Rugby sevens is a variant of the rugby union 15-a-side game format. Although played with only seven on-field players the field dimensions for rugby sevens align with that of its 15-a-side counterpart. Generally, the same rules apply apart from a few variations incorporated to accommodate this abbreviated style of rugby. The duration of a standard rugby union match is 80 min. However, the rugby sevens game is played over two halves of seven minutes, with a one-min half-time break. Additionally, the duration of a final at a sevens' tournament can be extended to 10-min halves, with a two-min half-time break, as seen in the HSBC World Rugby Sevens Series, The Rugby World Cup

Sevens, Commonwealth Games and Olympic Games (World Rugby, 2016a).

The rules and regulations specifically applying to rugby sevens, were designed primarily to speed up the game and to account for the reduced number of players, as summarised in Table 2.1 (World Rugby, 2009).

Table 2.1 Differences in rules between rugby sevens and 15-a-side formats of rugby union

Rules	Rugby Sevens	Rugby Union
Number of players	7 players on the field for each team	15 players on the field for each team
Substitutions/Interchanges	5 substitutions, 5 interchanges	7 substitutions, 7 interchanges
Scrums	3 players from each team	8 players from each team
Halves	7 min halves	40 min halves
Duration of a final	10 min halves	-
Half-time	1-2 min break	15 min break
Drawn matches	Matches drawn after regulation time are continued into a sudden-death extra time of multiple 5-min periods	
Conversions	All conversion attempts must be drop-kicked and must be taken within 40 s of scoring a try	All conversion attempts can either be drop-kicked or place-kicked and must be taken within 60 s of scoring a try
Yellow card offences	Player receives a 2 min suspension, and a power play is awarded to the opposing team	Player receives a 10 min suspension
Advantage	Referee must decide on advantage quickly, with one play usually ending the advantage	Referee can allow advantage for multiple plays
Kick-off	The team which has just scored kicks-off	The conceding team kicks-off
Additional officials	In major competitions and tournaments additional officials are required to avoid unnecessary delays during a game (in-goal touch judges who rule on the success of kicks at goal and questionable try scoring opportunities)	

The same scoring system applies to both codes, but in rugby sevens' scoring occurs more frequently than the 15-a-side game due to reduced player density (Forbes, 2013). As games are much shorter in duration rugby sevens tournaments are often played over a weekend with multiple games being played on the same day and over consecutive days (Dziedzic & Higham, 2014). In addition to the requisite competition for the Championship Cup many sevens tournaments also include a Plate Round, a Bowl, and a Shield (IRB Sevens, 2016). This means teams play more games, placing greater physical demands upon the players. Teams play at least five games and up to a maximum of six games during a tournament. If the tournament is held over two consecutive days, an average of three games is played a day. If the tournament spans three consecutive days, the number of games can vary from one to three. Generally, around the world, elite tournaments are held in the summer season and with the high-intensity short-duration nature of the game and back-to-back games, it is extremely important to consider the specific match demands and physical demands (Suarez-Arrones et al, 2012).

Men's rugby sevens is popular at all levels and played in almost all regions of the world, but is most popular in the South Pacific (Ross, Gill & Cronin, 2015a). Rugby sevens for women is an emerging sport, following suit of the men's popularity and regions. The format of this game has proven very successful, reflected in the popularity of major tournaments such as the Hong Kong Sevens, Wellington Sevens, and Dubai Sevens (all of which are included in the annual HSBC World Rugby Sevens Series), the Rugby World Cup Sevens and the Commonwealth Games. The overall success of the game led to both men's and women's competitions being included in the Olympic Games for the first time in Rio 2016 (World Rugby, 2016b).

When considering the International World Rugby Sevens Series Standings 2015/16 for men and women (Table 2.2 and 2.3), there is a considerable difference in points between the 1st and 10th placed teams in the women's standings compared to the men's standings. This considerable difference could be due to the lack of depth and quality of the women's game as it is a relatively new sport in comparison to the established men's game. For men, Fiji (1st place) had a total of 181 points, and nearly double that of Scotland (10th place) on 87 points. For women, Australia (1st place) had a total of 94 points and Brazil (10th place) had a total of 12 points i.e. Australia has seven times more points than Brazil.

Table 2.2 Men's International World Rugby Sevens Series Standings 2015/16 (World Rugby Official Website, 2015/16c).

Team	Dubai	Cape Town	Wellington	Sydney	Las Vegas	Vancouver	Hong Kong	Singapore	Paris	London	Points
Fiji	22	13	17	17	22	15	22	19	19	15	181
South Africa	13	22	19	15	17	19	17	17	13	19	171
New Zealand	15	10	22	22	13	22	19	12	10	13	158
Australia	12	10	13	19	19	17	15	10	12	7	134
Argentina	10	19	12	13	10	5	8	15	15	12	119
USA	17	12	10	10	15	12	12	7	5	17	117
Kenya	5	15	10	12	10	1	10	22	10	3	98
England	19	7	15	10	1	5	13	5	7	10	92
Samoa	10	3	8	7	3	13	5	13	22	5	89
Scotland	7	8	7	5	5	10	7	8	8	22	87

Table 2.3 Women's International World Rugby Sevens Series Standings 2015/16 (World Rugby Official Website, 2015/16d).

Team	Dubai	Brazil	USA	Canada	France	Points
Australia	20	20	20	16	18	94
New Zealand	12	16	18	18	16	80
Canada	10	18	14	12	20	74
England	16	8	16	20	14	74
France	14	12	8	14	12	60
USA	2	14	12	8	10	46
Russia	18	4	10	6	4	42
Fiji	8	10	6	4	6	34
Spain	6	2	2	10	8	28
Brazil	3	6	-	3	-	12

2.2 History of Rugby Sevens

The first officially sanctioned rugby sevens international tournament, the International Seven-A-Side Tournament, was held at Murrayfield in 1973 as part of the "Scottish Rugby Union's Celebration of Rugby" centenary festival (World Rugby, 2016b). The Hong Kong Sevens tournament was set up three years later, followed by the Rugby World Cup Sevens in 1993. National teams also compete for the Melrose Cup, named after Melrose (England) where the game was said to have originated back in 1883 (World Rugby, 2016b).

The game expanded with the World Rugby Sevens Series, which includes the three most well-known tournaments, the Hong Kong Sevens, Wellington Sevens and the Dubai Sevens (Van Rooyen, 2015). Men's rugby sevens debuted at the Commonwealth Games in Kuala Lumpur (1998). New Zealand has won the gold medal four out of the five times with South Africa winning in 2014. The International Olympic Committee's (IOC) 2009-2012 Final Report stated the inclusion of rugby sevens in the Rio 2016 Olympic Games under the 'Major Decisions of the IOC Sessions' section (IOC, 2012), expanding the game even further and including women. While men's rugby sevens have been part of the Commonwealth Games since 1998, it has taken another 20 years for women's rugby sevens to be included for the first time at the 2018 Gold Coast Commonwealth Games (Australian Rugby Union (ARU), 2014).

2.2.1 Women's Rugby Sevens

The first women's rugby union international (Netherlands vs. France) was played 111 years after the first men's rugby union international. In 1990, New Zealand hosted the first international tournament, dubbed "Rugby-fest", featuring teams from the Netherlands, US and Russia. New Zealand has dominated the women's rugby union scene since its inception (Mortimer, 2013).

It was not until 1997 that a women's rugby sevens competition was included in the annual Hong Kong Sevens tournament (1 of 10 tournaments that made up the World Rugby Sevens series). From 1997 to 2007 New Zealand/Aotearoa Maori Women's Rugby Sevens team (playing as New Zealand) were champions of the Hong Kong Sevens. New Zealand dominated the sport for a decade before the US won the tournament in 2008 with New Zealand failing to send a team (World Rugby, 2016a). During this period women's rugby sevens was not treated as a competitive sport, very few countries were involved, and the players involved came from rugby union.

It was not until 2009 that women's rugby sevens started to be taken more seriously. Following the IOC's decision in 2009 to include rugby sevens for both men and women in the 2016 Rio Olympics, many of the national rugby unions elected to incorporate the women's game into their strategic plans from 2011 onwards. This was with the express intention to make rugby sevens a popular choice for female athletes, growing and developing the game for the 2016 Olympics (World Rugby, 2011a). In 2009 the inaugural Women's Rugby World Cup Sevens tournament was held in Dubai alongside the men's tournament. Australia defeated New Zealand to become the first team to win the Women's Rugby Sevens World Cup. The tournament was then held in Russia in 2013, again in conjunction with the men's tournament, and this time New Zealand were crowned champions (World Rugby, 2016b).

With the strategic plans implemented during 2011/12, women's rugby sevens made a rapid change from amateur to professional, in an extremely short period of time. The inaugural IRB Women's Sevens World Series was held in the 2012/13 season using the same model as the men. There were four rounds of competition played in Dubai, Houston, Guangzhou and Amsterdam, with six core teams from Australia, Canada, England, Netherlands, USA and New Zealand. The following series in 2013/14 saw the number of core teams increased to eight, which was again increased to eleven for the 2014/15 and 2015/16 series (World Rugby, 2016b). New Zealand won the first three series, with Australia winning the 2015/16 series (World Rugby, 2016b).

With the inclusion in the 2016 Olympics and 2018 Commonwealth Games, the game achieved significant growth in a short period of time (5-6 years) (World Rugby, 2016e).

With the game going from an amateur to professional status so fast, this has led to the need for rapid developments in physical attributes of players.

2.2.2 Rugby, Rugby Sevens and the Olympics

Rugby had not been played at the Olympics since the 1924 games held in Paris. Since then the IRB created the Women's Rugby Plan 2011-2016 with goals and key performance indicators that can be seen in Appendix 1 (World Rugby, 2011a), placing the game in the Rio 2016 Olympics.

With the decision in 2009 to include rugby sevens at the Olympics and the creation and implementation of the strategic plan, global playing numbers increased as did the professionalism of the game. Tournaments have grown and expanded since the implementation of the strategic plan, including the 2016 Olympics, (Appendix 2; World Rugby, 2011b). The IRB stated global female participation had increased from 1.5 million in 2013 to 1.77 million in 2014 (World Rugby, 2015b). This number increased again to an estimated 2 million female participants across 110 different countries by 2016 (World Rugby, 2016e).

2.2.3 Football History and the Olympics

Football (soccer) has the most participants of any sport in the world for both males and females (FIFA, 2017a). It has been stated that over 235 million males and 30 million females play football worldwide (FIFA, 2007; FIFA, 2015). The first FIFA World Cup for men was played in 1930 and the game has continued to grow and develop all around the world (FIFA, 2017b) and there are now 209 national teams competing to qualify for the 32 places at the 4-yearly showpiece event (FIFA, 2017c). The first FIFA Women's World Cup was played in 1991, 61 years after the first men's World Cup and there are now 128 national teams competing to qualify for the 24 places (FIFA, 2015a).

Being the most popular sport in the world for both men and women means the sport has great depth with millions of youth participating in the sport (FIFA, 2007). There are FIFA World Cup competitions for both male and female youth teams with the first U-20 Women's World Cup held in 2002, and the first U-17 Women's World Cup held in 2008 (FIFA, 2015a).

Football for men has been a part of the Olympic games since the second Olympics in Paris 1900 and women made their first appearance at the Olympic games in Atlanta in 1996 (Olympics, 2017).

2.2.4 Track and Field Athletics History and the Olympics

Track and field athletics consists of events that require the use of skills such as running, jumping and throwing. Track and field athletics is one of the oldest sports and was a part of the Ancient Games prior to the formation of the modern Olympic Games. The first event contested in the Ancient Games was a 192-metre sprint known as the "stadium" race, and winners have been recorded since 776 BC (IOC, 2017). Athletics is the leading sport of the Olympic Games, which it has been a part of since its inception in 1896 (Berthelot et al, 2015).

In 1912, the International Amateur Athletic Federation (now known as the International Association of Athletics Federation, IAAF) was established, and currently has 215 member federations (countries) (IAAF, 2017). The IAAF is responsible for hosting major athletics competitions worldwide such as the World Athletic Series, which includes IAAF World Championships in Athletics, IAAF World Indoor Championships in Athletics and IAAF World Youth Championships in Athletics, and one-day events that include the IAAF Diamond League, IAAF World Challenge Meetings and IAAF World Indoor Tour (IAAF, 2017).

Previously considered an exclusive male only sport, athletics changed in 1921 when the first Women's World Games took place. Track and field athletics for women was first included in the 1928 Olympics in Amsterdam, and has since been a permanent fixture at the games (IOC, 2017). The difference between the world records (WR) for men and women in track and field athletics is a clear example of the physical capability/differences between elite male/female athletes, and provides a benchmark of sex performance gaps seen across sports. However, it is not a direct comparison of the type/style of running performed in the respective sports discussed, and there are other factors that affect match-running outputs in team based sports involving a range of different skills.

2.3 Physiological differences between males and females

There are obvious physiological differences between males and females, which contribute to expected differences in overall sporting performance. Testosterone is the primary male hormone and estrogen is the primary female hormone, both play important roles in the development of distinctive biological differences between the sexes (García, 2015).

It is common that two sexes from the same species can exhibit different characteristics beyond the differences of their sexual organs and this is referred to as sexual dimorphism (Mazzei, 2017). Among humans, sexual dimorphism includes differentiation in muscle mass, height, internal genitals, external genitals, breasts, the endocrine (hormonal) systems and their physiological and behavioural effects (Mazzei, 2017; Rigby & Kulathinal, 2015).

Generally, research suggests that males are typically larger than females and that they possess greater muscle mass (Rigby & Kulathinal, 2015; Crewther, Obminski & Cook, 2016). This is clearly evident during puberty, where adolescent males body size, muscle strength and anabolic hormones all increase dramatically, compared to adolescent females (Crewther, Obminski & Cook, 2016).

2.3.1 Anthropometry/Physiology

Body size and physiological differences between males and females, in relation to the construction of body mass, greatly contributes to both absolute and relative maximum volume of oxygen (VO_{2max}) uptake among athletes (Haugen et al, 2017). Females have a higher body fat percentage and lower hemoglobin concentration (Sandbakk, Soli & Holmberg, 2017) compared to males, and males have a higher muscle mass which contributes to a higher percentage of total body mass (Sandbakk, Soli & Holmberg, 2017). To understand the performance gap between sexes, body size differences between males and females is highly relevant and needs to be considered when comparing the two as higher muscle mass and lower body fat is known to increase VO_{2max}, which results in greater athletic performance in team-based field sports (Cronin & Hansen, 2005; Hori et al, 2008).

Normative values of body fat for elite athletes is considered to be 5-10% for males and 8-15% for females, with 11-14% for males and 16-23% for females considered healthy, and acceptable values of body fat for males is 15-20% and 24-30% for females (Jeukendrup & Gleeson, 2010; Turocy et al 2011).

Table 2.4 General Population verses national level athletes from a range of sports (males and females) (Geisler et al, 2016; Kyle et al, 2003; Prior et al, 2001; Wan Nudri, Ismail & Zawiak, 1996).

Sex	Height (cm)		Weight (kg)		BMI (kg/m^2)		Body Fat Percent (%)	
	GP	NA	GP	NA	GP	NA	GP	NA
Male	180.9	1.85	80.2	97.8	19.9	22.9	16.5	13.8
Female	169.6	1.66	76.1	58	19.6	20.9	27.4	24.7

*cm = centimetres *kg = kilograms *GP = general population *NA = national level athelets * BMI = Body Mass Index *(kg/m^2) = kilogram per square metre

Table 2.4 presents figures for the general population verses national level athletes from a range of different sports (male and female). The studies reported (Geisler et al, 2016; Kyle et al, 2003), suggest that, males from the general population and national level athletes are taller and weigh more than females from the general population and national level athletes. They also have a lower body fat percentage of 16.5% and 13.8% compared to females of 27.4% and 24.7% (Geisler et al, 2016; Kyle et al, 2003; Prior et al, 2001; Wan Nudri, Ismail & Zawiak, 1996).

Given these anthropometric differences between males and females of the general population and national level athletes from different sports, there are anticipated differences between elite male and female athletes in rugby sevens. It is important to note that population-related differences exist around the world and that the figures presented are reported as general population and national level athletes from a range of different sports, and do not investigate specific geographical populations or specific sports.

2.3.2 Testosterone/Estrogen

Androgenic hormones have performance-enhancing effects, specifically on strength, power and speed, which provide a competitive advantage in sports (Muller, 2016; Caplan & Parent, 2017). Increased muscle mass and increased strength and power aids sporting performance by increasing an athlete's ability in relation to aerobic endurance, anaerobic endurance, speed, physical strength and explosiveness (Cronin & Hansen, 2005; Hori et al, 2008). Specifically testosterone (primary male hormone), has gained the most attention because of its well-known effects on skeletal muscle growth (Argus et al, 2009; Cardinale & Stone, 2006). The human body naturally produces testosterone, but the level of testosterone in males versus females is extremely different. Females typically produce between 5-10% of the testosterone that males produce (Cardinale & Stone, 2006; García, 2015).

Research further suggests that men possess superior muscle strength due to having larger muscle fibres (Miller et al, 1993), relating also to bone structure. During adolescence, it is particularly evident that the increase of testosterone levels in males is responsible for muscle growth and muscle strength, which coincide with large growth in bone strength and dimensions (Lang, 2011). There are also gender differences in thermoregulation that also connect to differences in body mass. Research suggests that because females generally have a larger ratio of body surface to body mass, a higher fat content and lower exercise capacity than males, their sweating response is lower and they are unable to maintain their core body temperature for as long (Kaciuba-Uscilko & Grucza, 2001). It is also apparent that there are sex differences in substrate utilisation as displayed in sedentary individuals (Ruby & Robergs, 1994). However, further research into substrate utilisation of elite athletes suggests that any apparent sex differences diminish as the level of fitness increases (Ruby & Robergs, 1994).

Research suggests that the female hormones, estrogen and progesterone, can negatively impact sporting performance (Lebrun, Joyce & Constantini, 2013). The menstrual cycle generally lasts 28 days and can be divided into two phases, during the first phase the body produces a low-level of hormones, while during the second phase the body produces much higher levels of both estrogen and progesterone (Constantini, Dubnov & Lebrun, 2005). As a result of the increased hormonal production, female athletes may experience changes in energy/fuel levels, changes in body temperature control, experience excessive fluid retention (bloating) and psychological changes (Lebrun, Joyce & Constantini, 2013). These hormonal changes mean that female athletes may suffer from depleted energy levels, be unable to cool down at a normal rate during exercise, and may reach a state of fatigue faster (Julian et al, 2017). If an athlete is experiencing any of these symptoms it can potentially have a negative impact on their sporting performance, and increase the risk of injury (Constantini, Dubnov & Lebrun, 2005).

Research on the oral contraceptive pill (OCP), used to manipulate the production of female hormones, suggest potential benefits for female athletes (Bennell, White & Crossley, 1999). Taking OCP allows female athletes to alter the menstrual cycle, decreasing the chances of suffering any of the mentioned symptoms and limiting potential decreases in sporting performance as a result (Lebrun, Joyce & Constantini, 2013; Constantini, Dubnov & Lebrun, 2005; Bennell, White & Crossley, 1999). This may be advantageous for female athletes specifically around tournaments and competitions.

2.3.3 Sporting Performance

Sex is a major factor influencing overall sporting performance. Within track and field athletics, the best sporting performances and world records generally show a difference of 5-12% between the best male and female athletes (Thibault et al, 2010; Haugen et al, 2017). The 100 m sprint is regarded as the ultimate test of human speed and anaerobic power (Mackala, Fostiak & Kowalski, 2015). The men's 100m sprint world record is 9.58 s while the women's is 10.49 s (Majumdar & Robergs, 2011), a difference of 0.91 s (9%). While rugby sevens players require multiple physical attributes and skill acquisitions that can also detract from a players speed when compared to elite sprinters, speed and power (anaerobic ability) are still key components in the game.

The 5000 m race is a test of aerobic endurance (Brandon, 1995) and is similar in duration to a rugby sevens game. The men's world record is 12:37.35 min (IAAF, 2016a) while the women's is 14:11.15 min (IAAF, 2016b), a difference of 1:34.80 min or 11.7%. These results between elite male and female athletes represent expected differences in overall sporting performance that may be present between rugby sevens males and females. It is also important to note that the sex gap present in these world records has been decreasing over time and females are becoming faster. Researchers have highlighted a rapid rate of performance gains in female athletes' relative to male athletes' over recent years (Tatem et al, 2004). However, when considering the variables of why this is occurring, performance gain trends for females should slow down and settle into a similar growth rate to males. Known physiological differences between males and females will be a key contributor in restricting the extent that female performance is able to reach (Tatem et al, 2004). A key variable contributing to the performance growth rate seen in female athletes across major sports is the recent step-up in professionalism.

2.4 Match Demands and Analysis of Rugby Sevens

The match demands of rugby sevens are characterised by a high level of intensity and short duration, and the complex nature of the game requires elite players to have well-developed overall physical fitness qualities, along with the ability to execute technical skills and employ tactical decisions at an elite level (Meir, 2012). The dynamic match demands of rugby sevens can make it difficult for coaches and support staff to clearly identify which aspects of physical, technical, and tactical development should be targeted in order to improve and enhance the overall performance level (Higham et al, 2012).

Match analysis is utilised across many sports and is an important component of understanding the requirements for optimal performance (Schoeman, Coetzee & Schall, 2017). Through appropriate match analysis, specific aspects of performance can be identified allowing training to be designed for specific improvements. Naturally, as technology has advanced, so have the techniques of the methods employed in the analysis of the specific aspects of overall sporting performance (Schoeman, Coetzee & Schall, 2017). Methods of match analysis include notational analysis and time-motion analysis. It is important to note that the techniques employed for these methods need to be reliable, objective and appropriate to the specific aspect of performance in question (Hughes & Franks, 2004).

2.4.1 Notational Analysis, Time-Motion Analysis and Techniques

Notational analysis is the recording of events ensuring there is an accurate and objective record of what happened (Carling, Williams & Reilly, 2005). This method/training analysis provides an objective record of both individual and team performance (Ross, Gill & Cronin, 2014). Tracking and analysing key skills (frequency performed, duration and characteristics) that are performed assists with the development of successful performances, both individually and as a team, and throughout a season(s) (Quarrie & Hopkins, 2007; James, Mellalieu & Jones, 2005).

Time-motion analysis focuses on the movement of an individual's activity during a match or training (Carling, Williams & Reilly, 2005). This method of match/training analysis is commonly used within intermittent team sports (Ross, Gill & Cronin, 2014; Austin, Gabbett & Jenkins, 2011; Deutsch, Kearney & Rehrer, 2007). Tracking and analysing player movement/patterns (total distance run, distance run across specific speeds and number/distance of sprints) assesses specific match demands of players within a specific sport (Ross, Gill & Cronin, 2014; Deutsch, Kearney & Rehrer, 2007; Duthie et al, 2006).

Different techniques for recording/capturing data on overall and specific aspects of and overall performance include hand notation, audio recording, coded mapping, global positioning system (GPS), video analysis, heart rate monitors, multi-stage fitness tests (beep tests, Yo-Yo tests), speed electronic gates, vertical jump tests, horizontal jump tests and strength tests (Dubois et al, 2017; Inglis & Bird, 2017; Hughes & Franks, 2004). Such techniques are critiqued below and throughout this review.

Hand notation, audio recording, coded mapping, video analysis and GPS analysis are some of the techniques used for analysing match performance in sports. Hand notation provides a hard copy of specific actions that are performed during a game or training but can be a challenge for the observer given the pace of the game (Quarrie & Hopkins, 2007; James, Mellalieu & Jones, 2005). Audio recording allows the observer to continuously watch and keep up with the pace of the game providing a record of activities performed (Carling, Williams & Reilly, 2005). Coded mapping requires a lot of attention and can be hard to execute while keeping up with the pace of the game. It is used to analyse a specific athlete and record on a map of the field, movements/patterns and activities performed (Carling, Williams & Reilly, 2005). Video analysis allows the observer to watch and replay player movement/patterns and activities performed during a game or training and provide feedback (Ross, Gill & Cronin, 2014); this task however can be time consuming.

GPS devices are utilised in elite sports including rugby sevens and football to analyse match-running performance as well as manage player loading in order to help prevent injuries (Cahill et al, 2013; Suarez-Arrones et al, 2012). GPS devices worn by players during training and games to track running patterns and match activities provide a reliable computerised record of events (Ross, Gill & Cronin, 2014; Duthie et al, 2006). GPS analysis has the ability to accurately analyse the overall match performance, as well as specific aspects of match performance such as running demands, total duration, total distances covered, distances covered across specific speed zones, speed levels, number of sprints performed and mapping of movement (Dwyer & Gabbett, 2012).

Techniques used for testing speed across specific distances in sports include stopwatch timing, GPS, radar devices, running speed footpods and wireless electronic timing gates (WETG) (Haugen & Buchheit, 2011). Stopwatch timing is dependent on human reaction, and is used when more advanced equipment is not available (Haugen & Buchheit, 2011). GPS is a reliable source, but relies on satelite transmisson (which can be a problem indoors) and equipment can be expensive (Haugen & Buchheit, 2011). Radar devices only record peak speed and can be difficult to use as they must align directly with the athlete (Haugen & Buchheit, 2011). Running speed foot-pods can be restricted to specific footwear and are commonly used on one foot, possibly impacting on speed time recorded depending on which foot starts front or back (Haugen & Buchheit, 2011). WETG is used widely across elite sports including rugby sevens and football, and is considered to be the most advanced and reliable technology for collecting high performance speed data (Haugen & Buchheit, 2011).

Techniques used for testing aerobic endurance levels in sports include; multi-stage fitness test (beep test), maximal oxygen consumption test (VO_{2max}), Birtwell 40 metre shuttle test, Cooper 12-minute run test, Yo-Yo tests and 30-15 Intermittent Fitness Test (30-15 IFT). The beep test is a continuous shuttle-running test considered to have a reliable correlation to actual VO_{2max} (Leger & Lambert, 1982). The maximal oxygen consumption test (VO_{2max}) test is a direct (lab-based) measure of oxygen consumption but can be time consuming and expensive (Noakes, Myburgh & Schall, 1990). The Cooper 12-minute run test is a reliable technique for testing large groups and the general population, however requires athletes to run at a consistent pace (Cooper, 1968). The Yo-Yo intermittent shuttle-running tests are seen to replicate game-like activity involving acceleration, deceleration and change of direction (Bangsbo, Iaia & Krustrup, 2008) and are considered to be an accurate and valid measure of aerobic endurance levels in elite sports (Krustrup at al, 2006). It is perceived to be more specific to the work demands of team-based field sports (including rugby sevens and football) than continuous-running endurance tests such as the beep test (Bangsbo, Iaia & Krustrup, 2008). The 30-15 IFT is similar to the Yo-Yo tests with its intermittent nature making it relevant to intermittent sports, however it is not commonly used resulting in no normative values (Buchheit, 2008).

The following sections look at match performance comparisons, speed comparisons and aerobic endurance comparisons, which use a range of data collection and analysis methods mentioned.

2.5 Key Physical Fitness Requirements of Rugby Sevens

There are many parameters of fitness which include cardiovascular/respiratory endurance, stamina, strength, power, speed, flexibility, agility, accuracy, balance and co-ordination (Koutedakis, 1995). Success in all elite sports, more specifically intermittent team sports such as rugby sevens, consists of a group of players or individuals that are considered to have been measured as fit or advanced in these fitness parameters in relation to their chosen sport (Koutedakis, 1995).

Coaches and trainers develop training sessions and training programmes to enable athletes to improve and develop these physical fitness parameters associated with specific skills in relation to their sport (Meir et al, 2001). Rugby sevens is a multi-functional sport that requires players to possess technical, tactical and physical skills that all contribute to overall sporting performance (Meir et al, 2001). The key fitness parameters that have been documented in rugby sevens will be discussed further in this section.

2.5.1 Match-Running Outputs

All movement patterns within a game must be assessed in order to accurately evaluate the specific match demands and performance of players (Ross, Gill & Cronin, 2015b). This type of research provides valuable information pertaining to high intensity running patterns and match activities performed during games. Coaches and trainers can then use this information to design and prepare specific training programmes that enhance overall performance levels (Dogramaci, Watsford & Murphy, 2011).

The results of the studies referenced in Tables 2.5, 2.6 and 2.7 used GPS devices to determine match-running outputs for male and female rugby sevens players and football players. It is important to note that there may be inconsistencies between GPS devices used across the different studies. GPS devices use satellite-based technology operated by transferring data from the GPS device on the athlete to the available satellites orbiting the earth (Johnston et al, 2014). This data is transferred using four sampling frequencies commonly used in sports (1 Hz, 5 Hz, 10 Hz and 15 Hz); the higher the sampling frequency, the more information is transferred per second, resulting in a more accurate GPS device. Research suggests that GPS devices sampling at 10 Hz and 15 Hz are more reliable and accurate than GPS devices sampling at 1 Hz and 5 Hz (Johnston et al, 2014). However, there are other factors playing a part in the validity of data, such as the number of available and connected satellites (Cummins et al, 2013).

Table 2.5 Mean international match-running outputs for male rugby sevens and football players

Sport	Study	Sample Size (no.)	Total Distance Covered (m)	Low Speed Running (m)	High Speed Running (m)	Max Speed (km)	Sprints (no.·game)
Rugby 7's (Forwards)	Ross, Gill & Cronin, (2015a)	27	1452 ± 243	1202 ± 206	252 ± 103	28.4 ± 2.9	7.90 ± 0.83
Rugby 7's (Backs)	Ross, Gill & Cronin, (2015a)	27	1420 ± 332	1173 ± 275	249 ± 130	30.2 ± 2.6	8.4 ± 0.72
Rugby 7's (Pool matches)	Rienzi, Reilly & Malkin, (1999)	27	1446 ± 299	1193 ± 251	254 ± 123	29.1 ± 2.5	
Rugby 7's (Cup matches)	Rienzi, Reilly & Malkin, (1999)	27	1423 ± 285	1180 ± 243	246 ± 117	29.6 ± 2.9	
Rugby 7's	Suarez-Arrones et al, (2012)	7	1580 ± 146	1363	217 ± 122	29.9	7.4
Rugby 7's mean/match			1464	1222	243	29.4	8
Football	Mohr, Krustrup & Bangsbo, (2003)	18	10860 ± 180	7780	2430 ± 140		
	Bradley et al, (2013)	190	10690 ± 996	9757 ± 357	931 ± 165		
	Mallo et al, (2015)	111	10793 ± 1153	8245 ± 433	2163 ± 328		
	Di Salvo et al, (2007)	300	11393 ± 1016	10417 ± 346	950 ± 149		
Football mean/match			10934	9050	1619		

*Rugby 7's = Rugby Sevens *no. = number *m = metres *km = kilometres * no.·game = number per game
*The means for each sport were calculated by adding each score together and dividing by the relative number of studies included

The data presented includes mixed positions for both sports (forwards and backs in rugby sevens, and defenders, midfielders, forwards, excluding goalkeepers in football). It appears that international rugby sevens forwards and backs match-running outputs remain consistent across tournament rounds (Table 2.5) (Ross, Gill & Cronin, 2015a; Rienzi, Reilly & Malkin, 1999; Suarez-Arrones et al, 2012). In the data presented international rugby sevens players cover a mean total distance of 1464 m (Ross, Gill &

Cronin, 2015a; Rienzi, Reilly & Malkin, 1999; Suarez-Arrones et al, 2012). Of the total distance covered, 83% (1222 m) was spent performing low intensity running and 17% (243 m) was spent performing high speed running. Players reach a mean maximum speed of 29.6 km and perform 8 high speed sprints per match; it is important to note there was no standard deviation reported (Suarez-Arrones et al, 2012). There is a slight difference reflected in low speed running with forwards spending more time running at lower speeds, while backs reach a higher maximum speed of 30.2 km (Higham et al, 2016). In the data presented, international football players cover a mean total distance of 10,934 m (calculated from the studies published in Table 2.4). Of the total distance covered, 83% (9050 m) was spent performing low intensity running and 15% (1619 m) was spent performing high speed running. The figures discussed for both rugby sevens and football are used as a benchmark for these sports within this thesis. It is important to note that the football data presented in Table 2.5 is for a 90-min match, while the rugby sevens data is for a 14-min match. The two sports are not being directly compared and are simply being presented.

Table 2.6 Mean international match-running outputs for female rugby sevens and football players

Sport	Study	Sample Size (no.)	Total Distance Covered (m)	Low Speed Running (m)	High Speed Running (m)
Rugby 7's (International Match)	Vescovi & Goodale, (2015)	16	1468 ± 88	1340 ± 57	128 ± 67
Rugby 7's (Pool)	Clarke, Anson & Pyne, (2014)	12	1120 ± 424		
Rugby 7's mean/match			1294		128
Football	Krustrup et al, (2005)	14	10300 ± 1600	8990	1310
	Bradley et al, (2014)	59	10754 ± 150	9977 ± 36	777 ± 18
	Pumpa et al, (2016)		9520 ± 890	7630 ± 910	1660 ± 440
Football mean/match			10191	8866	1249

*Rugby 7's = Rugby Sevens *no. = number *m = metres

*The means for each sport were calculated by adding each score together and dividing by the relative number of studies included

The data presented includes mixed positions for both sports (forwards and backs in rugby sevens, and defenders, midfielders, forwards, excluding goalkeepers in football). From the data presented the total distance covered during an international rugby sevens match is greater than during a pool game in a tournament setting (Table 2.6). Players cover a mean total distance of 1294 m with 10% (128 m) of this distance spent performing high speed running. Due to limited data an average figure for low speed running was not obtainable. There was little difference in the running demands for men across the game types whereas the above data for women shows a large deficit of 348 m (27%) during pool play compared to an international match. The lack of player depth and history of the game could be a contributing factor, as training and/or game experience increases a player's ability and performance (Goodale et al, 2016). This could also apply across nations as a lack of tournament experience could also be a contributing factor to such a deficit (Table 2.6). International football players cover a mean total distance of 10,191 m (Table 2.6). Of the total distance covered, 87% (8866 m) was spent performing low intensity running and 12% (1249 m) was spent performing high speed running. Due to multiple differences between rugby sevens and football such as match duration, intensity of contact, directional constraints, number of players and field dimensions, minimises the direct use of football research to rugby sevens. However, the sex gaps established between elite male and female football can be used as a benchmark for performance standards between elite male and female rugby sevens.

Table 2.7 Mean international match-running output comparisons of male and female rugby sevens and football players

Sport & Gender	Study	Total Distance Covered (m)	Low Speed Running (m)	High Speed Running (m)	Pool Play (Total Distance Covered - m)
Rugby 7's Men	Ross, Gill & Cronin, (2015a); Rienzi, Reilly & Malkin, (1999); Suarez-Arrones et al, (2012)	1464	1222	243	1446
Rugby 7's Women	Match Vescovi & Goodale, (2015); Clarke, Anson & Pyne, (2014)	1294	-	128	1120
Rugby 7's Difference		170	-	115	326
Rugby 7's Percentage Difference		12%	-	62%	25%
Football Men	Mohr, Krustrup & Bangsbo, (2003); Bradley et al, (2013); Mallo et al, (2015); Di Salvo et al, (2007)	10934	9050	1619	
Football Women	Krustrup et al, (2005); Bradley et al, (2014); Pumpa et al, (2016)	10191	8866	1249	
Football Difference		743	184	370	
Football Percentage Difference		7%	2%	26%	

*Rugby 7's = Rugby Sevens *m = metres

Male rugby sevens players cover 12% more ground overall (170 m) than female rugby sevens players (Table 2.7). They also cover 62% more distance in high speed running (115 m). Based on the figures above, during pool matches, female international rugby sevens players cover 25% (326 m) fewer metres than men. This suggests there is potential for the women in pool matches to increase match-running outputs based on the physiological performance gap (11.7%) between male and female elite athletes for the 5000 m race (Majumdar & Robergs, 2011; IAAF, 2016a; IAAF, 2016b; IWF, 2016a; IWF, 2016b) which is similar in duration to rugby sevens game. The results also show that male football players cover 7% more ground overall (743 m) than female football players. Males also cover 2% more distance in low speed running (184 m) and 26% more distance in high speed running (370 m). The difference between male and female football players' total distance covered is 7% and low speed running is 2%, placing the performance gap within and better than the theoretical expected elite sex gap of 5-12%.

2.5.2 Speed

Speed and acceleration are key physical components in the majority of field-based sports (Duthie, Pyne & Hooper, 2003). In order to achieve success most field-based sports require a player to have the capability to cover distances quickly from varying starting speeds and positions whilst executing and performing sport-specific skills (Nicholas, 1997; Di Mascio & Bradley, 2013). Given the field dimensions and number of players, the game demands that competitive players have greater ability to cover ground as fast as possible and, the faster a player is the more advantage they will have during a game (Duthie, 2006; Rampinini et al, 2007).

Research studies (Ross, Gill & Cronin, 2015b; Higham et al, 2013) reported sprint times in elite rugby sevens using WETG to assess athletes' running speed over specific distances such as 0-10, 20, 30 and 40 m. Usually, an athlete is provided with three attempts to produce his/her best effort, with provision for an adequate rest period between each attempt (2-5 min recovery), and the fastest time across all attempts is recorded (Goodale et al, 2016). The results of the studies referenced in Tables 2.8 and 2.9 used the WETG sprint testing technique, testing male and female international athletes across selected sports, and these results are therefore utilised in this review for consistency of comparison. There may be inconsistencies between studies in relation to the testing protocols not described such as exposure to environmental factors, running surface, footwear and starting stance.

Table 2.8 Mean international sprint times for male rugby sevens, rugby union and football players

Sport	Study	Sample Size (no.)	10 m (s)	20 m (s)	30 m (s)	40 m (s)
Rugby 7's	Higham et al, (2013)	18	1.74 ± 0.06	2.92 ± 0.08	4.02 ± 0.11	5.11 ± 0.15
	Ross, Gill & Cronin, (2015b)	65	1.68 ± 0.05			4.99 ± 0.11
Rugby 7's Mean			1.71 ± 0.05			5.05 ± 0.12
Rugby Union	Smart, (2011)	1161	1.68 ± 4.4	2.89 ± 3.3	4.11 ± 3.9	
	Randall, Furlong & Harrison, (2014)	21			4.51 ± 0.27	
Rugby Union Mean					4.31 ± 3.87	
Football	Pasquarelli et al, (2009)	154	1.76 ± 0.07	3.01 ± 0.03	4.17 ± 0.03	5.33 ± 0.05
	Ronnestad et al, (2008)	21	1.74 ± 0.01			5.30 ± 0.04
	Haugen et al, (2014)	134	1.60	2.89	4.08	5.26
	Wisloff et al, (2004)	17	1.82 ± 0.30	3.00 ± 0.30	4.00 ± 0.20	
Football Mean			1.73 ± 0.11	2.96 ± 0.09	4.08 ± 0.07	5.29 ± 0.05

*Rugby 7's = Rugby Sevens *no. = number *m = metres *s = seconds

*The means for each sport were calculated by adding each score together and dividing by the relative number of studies included and the standard deviation were determined using a pooled variance calculator (Pooled Variance Calculator, 2018).

The data presented includes mixed positions for all three sports (forwards and backs in rugby sevens and rugby union, and all positions in football excluding goalkeepers). Speed is extremely important for rugby sevens players and rugby union backs as they frequently cover longer distances of over 20 m at maximal effort (Spinks et al, 2007). Based on the data presented in Table 2.8 sprint times over 10 and 20 m across rugby sevens, rugby union and football appear to be similar (Table 2.8). When looking at the rugby sevens data and the football data presented, international rugby sevens players appear to be faster over 30 and 40 m.

Table 2.9 Mean international sprint times for female rugby sevens, rugby union and football players

Sport	Study	Sample Size (no.)	10 m (s)	20 m (s)	30 m (s)	40 m (s)
Rugby 7's	Goodale et al, (2016)	24	1.83 ± 0.05		4.41 ± 0.13	5.66 ± 0.16
Rugby Union (Backs)	Hene, Bassett & Andrews, (2011)	32	1.90 ± 0.07	3.34 ± 0.09		5.77 ± 0.19
Football	Haugen, Tonnessen, & Seiler, (2012 Haugen et al, (2014)	194 134	1.77 ± 0.06 1.79	3.15 ± 0.06 3.23	4.45 ± 0.06 4.64	5.74 ± 0.06 6.02
Football Mean			1.78 ± 0.06	3.19 ± 0.06	4.54 ± 0.06	5.88 ± 0.06

*Rugby 7's = Rugby Sevens *no. = number *m = metres *s = seconds
*The means for each sport were calculated by adding each score together and dividing by the relative number of studies included.

The data presented includes mixed positions for rugby sevens (forwards and backs) and football (defenders, midfielders, forwards, excluding goalkeepers), and one position in rugby union (backs). From the data presented it appears that football players' sprint times over 10 and 20 m are the fastest (Table 2.9). It is important to note there is no publically reported 20 m sprint time data for rugby sevens players. These results are different to the results presented in the men's data, where rugby sevens, rugby union and football have similar sprint times over 10 and 20 m. Female rugby sevens players appear to be the fastest over 30 and 40 m, which is the same overall outcome as the men.

Women's football is one of the fastest growing female sports in the world with 30 million female (girls/women) players (FIFA, 2015b). Women's rugby is estimated to have 28 million fewer female players than women's football (World Rugby, 2016e). The first World Cup for women's football was played in 1991 (FIFA, 2016), 18 years before the first women's rugby seven's World Cup. This may be a contributing factor in the speed differences shown, as research has shown that success at an elite level can be linked to grassroots participation in sports (Jacobs, 2014; Pederson & Seidman, 2004). Cumulative years of playing from a younger age improves physical and psychological outcomes for adolescents and adults (Pederson & Seidman, 2004). A lack of research on women's rugby sevens players may also be a factor in the differences shown.

Table 2.10 Mean international sprint comparisons of male and female rugby sevens, rugby union and football players

Sport	10 m (s)		20 m (s)		30 m (s)		40 m (s)	
	M	W	M	W	M	W	M	W
Rugby 7's	1.71	1.83	2.92		4.02	4.41	5.05	5.66
Study	Higham et al, (2013); Ross, Gill & Cronin, (2015b)	Goodale et al, (2016)	Higham et al, (2013)		Higham et al, (2013)	Goodale et al, (2016)	Higham et al, (2013); Ross, Gill & Cronin, (2015b)	Goodale et al, (2016)
Rugby 7's Percent Diff	7%				9%		11%	
Rugby Union	1.68	1.90	2.89	3.34	4.31	-		5.77
Study	Smart, (2011)	Hene, Bassett & Andrews, (2011)	Smart, (2011)	Hene, Bassett & Andrews, (2011)	Smart, (2011); Randall, Furlong & Harrison, (2014)			Hene, Bassett & Andrews, (2011)
Rugby Union Percent Diff	12%		14%					
Football	1.73	1.78	2.96	3.19	4.08	4.54	5.29	5.88
Study	Pasquarelli et al, (2009); Ronnestad et al, (2008); Haugen et al, (2014); Wisloff et al, (2004)	Haugen, Tonnessen, & Seiler, (2012); Haugen et al, (2014)	Pasquarelli et al, (2009); Haugen et al, (2014); Wisloff et al, (2004)	Haugen, Tonnessen, & Seiler, (2012); Haugen et al, (2014)	Pasquarelli et al, (2009); Haugen et al, (2014); Wisloff et al, (2004)	Haugen, Tonnessen, & Seiler, (2012); Haugen et al, (2014)	Pasquarelli et al, (2009); Ronnestad et al, (2008); Haugen et al, (2014)	Haugen, Tonnessen, & Seiler, (2012); Haugen et al, (2014)
Football Percent Diff	3%		7%		11%		11%	

*R7 = Rugby sevens *RU = Rugby Union *FB = Football *m = metres *s = seconds *M = Men *W = Women *Diff = Difference *% = percent.

Table 2.10 shows the differences in speed over 10, 20, 30 and 40 m between male and female players across three different codes. Table 2.10 highlights the physiological difference between males and females in relation to speed. Performances of the best male and female elite athletes generally differ by 5-12%, the difference mainly being attributed to men being under a stronger influence of and producing significantly more androgenic hormones than women (Muller, 2016; Caplan & Parent, 2017).

The overall difference between elite male and female football players over 40 m is 11% (0.59 s). In rugby sevens the overall difference in speed over 40 m between men and women is also 11% (0.61 s). Based on the elite sex performance gap figure of 9% between the fastest male and female sprinters, both female football and rugby sevens players have the potential to increase speed when compared to their male counterpart, lowering the current percentage difference.

2.5.3 Aerobic Endurance/Fatigue

Fatigue is the body's way of restricting exercise at an intensity or duration that could lead to physical harm, resulting in the athlete slowing down or stopping altogether (Rampinini et al, 2009; Enoka & Duchateau, 2008). This occurs when energy systems are no longer able to supply sufficient oxygen to the muscles, or the athlete is unable to maintain lactate levels, phosphate levels, hydrogen ion levels, glycogen stores and/or body temperature (Enoka & Duchateau, 2008). Athletes who compete in high-intensity sports such as rugby sevens may experience fatigue during a game, between games and after a tournament. However, it can be attenuated for a period of time with specific conditioning training, optimal nutrition and a balanced training schedule (Mohr, Krustrup & Bangsbo, 2005).

Elite athletes in high-intensity sports endure a high volume of trainings and competitions. Different periodisation training phases are often implemented at this level to prepare for competition, which can include periods of intensified loads (overload training), periods of lower intensity loads (under load training) and periods of maintenance (Woods et al, 2017). Specifically, intensified training periods can lead to athletes experiencing more fatigue, and temporary decrements in performance levels. This phase of training is designed to place athletes under increased stress loads to force the body to adapt (resisting fatigue during exercise for longer and between training sessions/games) and therefore enhance performance levels (Woods et al, 2017). An increase in performance levels is dependent on the use of the appropriate recovery procedures. If an imbalance occurs and recovery is not sufficient for the increase in training load, athletes may experience severe levels of fatigue that could lead to an injury (Purvis, Gonsalves & Deuster, 2010). Successful training programmes and environments include a well-balanced plan inclusive of improving an athlete's ability to resist fatigue and increasing aerobic endurance levels (Robson, Gleeson & Ansley, 2009).

Aerobic metabolism is the body's process that transports oxygen and nutrients to the muscles and removes metabolic waste (Matsakas & Patel, 2016). Aerobic endurance training can enhance the body's ability to oxidise carbohydrates and fats (Matsakas & Patel, 2016). Improving oxygen, blood and nutrient flow to the working muscles improves recovery between bouts of exercise, lengthening an athlete's ability to perform and resist fatigue (Tomlin & Wenger, 2002).

The human body uses the aerobic energy system in the execution of intermittent sports such as rugby sevens (Hogarth, Burkett & McKean, 2016). The more efficient an athlete's aerobic energy system, the faster the recovery between high intensity sprints and work outputs during a game, as well as recovery after high intensity training or games (Baker, 2015). An athlete with a superior aerobic endurance level is able to perform for longer at higher intensities during a game and also able to replicate and sustain the same performance level for longer (Tomlin & Wenger, 2001).

Level 1 of the Yo-Yo Intermittent Recovery Test (YYIRT1) requires players to run a sequence of increasingly faster 20-m shuttles until exhaustion, resulting in an overall score and an accumulative distance. The level one test operates on 10 s of active recovery between shuttles. The results of the studies referenced in Tables 2.11 and 2.12 implemented the YYIRT1 test on male and female athletes across selected sports. It is important to note, as previously mentioned, there may be inconsistencies between studies in relation to the testing protocols not described.

Table 2.11 Mean international YYIRT1 for male rugby sevens, rugby union and football players

YYIRT1				
Sport	Study	Sample Size (no.)	Distance (m)	Score (level)
Rugby 7's	Higham et al, (2013)	18	2256 ± 268	19.5 ± 0.7
Rugby Union	Austin, Gabbett & Jenkins, (2013)	36	2040 ± 440	18.8 ± 0.6
	Tanner & Gore, (2013)	1 Team (international)	1951 ± 419	18.6 ± 1.2
Rugby Union Mean			1995 ± 432	18.7 ± 0.9
Football	Bangsbo, Iaia & Krustrup, (2008)	25	2420	20.1
	Fanchini et al, (2014)	24	2130 ± 298	19.2 ± 0.6
Football Mean			2275 ± 298	19.6 ± 0.6

*Rugby 7's = Rugby Sevens * YYIRT1 = Yo-Yo Intermittent Recovery Test Level One *no. = number *m = metres
*The means for each sport were calculated by adding each score together and dividing by the relative number of studies included and the standard deviation were determined using a pooled variance calculator (Pooled Variance Calculator, 2018).

The data presented includes mixed positions for all three sports (forwards and backs for rugby sevens and rugby union, and all positions excluding goalkeepers for football). In comparison to rugby sevens and football, rugby union players, in the data presented, cover less distance and have the lowest YYIRT1 score of 18.7, nearly a whole level lower than both rugby sevens and football players (Table 2.11). Rugby sevens and football players on average cover a greater distance and have higher YYIRT1 scores of 19.5 (rugby sevens) and 19.6 (football). Having nearly the same YYIRT1 scores, suggests that rugby sevens and football require their international players to have a similar high level of aerobic endurance.

These sports are extremely different in duration of a standard game, football is a 90-min game and rugby sevens is a 14-min game. However, rugby sevens games are played in a tournament-style format over two consecutive days. Players are required to play up to three games in one day and up to six games in total over two days. Therefore, players can perform up to a maximum of 84 minutes over the course of a tournament, very similar to one 90-min football game. International/elite level football games usually take place once or twice a week, and players are not required to play back-to-back games over consecutive days. The training requirements for both rugby sevens and football players are therefore similar with both performing between 4-6 field sessions and 2-3 gym sessions per week (Elloumi et al, 2012; Los Arcos et al, 2015).

Table 2.12 Mean international YYIRT1 for female rugby sevens and football players

YYIRT1				
Sport	Study	Sample Size (no.)	Distance (m)	Score (level)
Rugby 7's	Clarke et al, (2014)	22	1200 ± 320	16.3 ± 1.0
Football	Bangsbo, Iaia & Krustrup, (2008)	25	1760	18.1
	Risso et al, (2017)	22	1690 ± 498	17.7 ± 0.6
Football Mean			1725 ± 498	17.9 ± 0.6

*Rugby 7's = Rugby Sevens * YYIRT1 = Yo-Yo Intermittent Recovery Test Level One *no. = number *m = metres
* The means for each sport were calculated by adding each score together and dividing by the relative number of studies included.

The data presented includes mixed positions for both sports (forwards and backs in rugby sevens, and defenders, midfielders, forwards, excluding goalkeepers in football). From the data presented female rugby sevens players cover less distance and have a lower YYIRT1 score of 16.3 than female footballers (17.9). It would be expected to see results closer to the men's data shown in Table 2.12. However, the results show female rugby sevens players as having a score 1.5 levels lower than female football players, a much greater gap than the men's results. It is important to note that the YYIRT1 results do appear to be slightly low for international female rugby sevens players; this could also be due to the lack of research and/or lack of depth and quality in players as the sport is relatively new.

Table 2.13 Mean YYIRT1 comparisons of male and female rugby sevens and football players

YYIRT1							
Sport	MEN		WOMEN		DIFFERENCE		
	Distance	Score	Distance	Score	Distance	Score	Percent %
Rugby 7's	2256 Higham et al, (2013)	19.5 Higham et al, (2013)	1200 Clarke et al, (2014)	16.3 Clarke et al, (2014)	1056	3.2	61
Football	2275 Bangsbo, Iaia & Krustrup, (2008); Fanchini et al, (2014)	19.6 Bangsbo, Iaia & Krustrup, (2008); Fanchini et al, 2014)	1725 Bangsbo, Iaia & Krustrup, (2008); Risso et al, (2017)	17.9 Bangsbo, Iaia & Krustrup, (2008); Risso et al, (2017)	550	1.7	28

*Rugby 7's = Rugby Sevens *YYIRT1 = Yo-Yo Intermittent Recovery Test Level One *Distance = Measurement in metres *Score = Measurement by Yo-Yo IR1 levels.

The differences in aerobic endurance between male and female international athletes playing rugby sevens and football are shown in Table 2.13. It also highlights the physiological difference between males and females in relation to aerobic capacity. The 5000 m race is similar in duration to a rugby sevens game; the men's world record is 12:37.35 (min) (IAAF, 2016a) and the women's is 14:11.15 (min) (IAAF, 2016b), a difference of 1:34.80 (min) or 11.7%. In measuring the presented rugby sevens' results, males cover an additional 1056 m (61%), than their female counterparts, a significantly greater distance, scoring a further 3.2 levels on the YYIRT1 test. Male footballers also achieved better results than their female counterparts, with a reduced distance margin of 550 m (28%) and a difference of 1.7 levels on the YYIRT1 test. As there is a greater difference (>11.7%) between male and female rugby sevens players and football players, the (theoretical) elite base figure suggests room for improvement in aerobic endurance levels, lowering the current percentage difference.

2.6 Summary of Literature Review

With the Olympics now the prime target for many athletes and the pinnacle sporting event for many sports, rugby organisations and nations around the world have committed to investing in rugby sevens, and the women's game in particular. Rugby sevens is considered a high-intensity short-intermittent sport, and its complex nature dictates that players must have well-developed overall physical fitness qualities and an ability to perform technical skills and tactical decision-making at an elite level. For purposes of male and female comparison, theoretical elite base figures were derived from track and field athletics world records and from football data (an established multiple sprint sport similar to rugby sevens).

Sex is a major determinant of athletic performance. Athletic performance between the best male and female elite athletes generally differs by 5-12%, mainly due to men being under a stronger influence of and producing significantly more androgenic hormones than women. Androgenic hormones have performance-enhancing effects, specifically on strength, power and speed, which may provide a competitive advantage in sports. These hormonal differences affect height, weight, body fat, muscle mass, aerobic capacity and anaerobic threshold, which impact upon athletic performance and capability.

GPS devices are used by practitioners to analyse overall match-running outputs and specific aspects of match performance. Total distance covered, high speed running and low speed running are useful tools to design appropriate training programmes to enhance athletes overall performance levels. Based on the available research, elite female rugby sevens players have the potential to increase the total distance covered during a game. While female football players fall within the expected elite sex performance range with results showing a smaller deficit compared to the men.

The established theoretical elite base figure for speed (from track and field world records) is a 9% advantage to male over female sprinters. Literature has shown that in rugby sevens the overall difference in speed over 40 m between males and females is 11% (0.61 s). This suggests room for improvement of female players' speed in rugby sevens. It also showed the overall difference between elite male and female football players speed over 40 m is 11% (0.59 s) suggesting that female football players have the potential to increase speed as well.

The theoretical elite base figure for aerobic endurance (from athletics world records) is a 11.7% advantage to male over female distance runners (5000 m). Literature has shown that male rugby sevens players cover an additional 61% (1056 m), than their female counterparts, on the Yo-Yo IRT1 test. This suggests female rugby sevens players have the potential to significantly increase aerobic endurance levels. Literature also shows that male footballers achieved better results than their female counterparts, with a reduced distance margin of 28% (550 m) on the Yo-Yo IRT1 test suggesting that female football players have the potential to increase aerobic endurance levels.

Due to the lack of available research on rugby sevens particularly at the ‘elite’ level, further investigation into the specific match demands experienced during a game of rugby sevens, both male and female, would be extremely beneficial for coaches and support staff. Rugby sevens for women is a growing sport that would benefit from specific areas of investigation including speed, power, strength, aerobic endurance and GPS match-running output analysis of players.

Chapter 3

METHODOLOGY

3.0 Comparative Approach

For the purpose of the current study, Global Positioning System (GPS) devices were employed to collect match-running output data from elite female rugby sevens players from a top 3 world-ranked team and football players from a top 20 world-ranked team. The data collected will be compared against the existing literature on match-running outputs of international male rugby sevens players and international male football players, to determine sex-specific and sport-specific differences between the players and codes. The data will also be compared internally, from 1st half to 2nd half, game-to-game and tournament-to-tournament.

3.1 Participants

The athletes who participated in the current study were all female. Rugby sevens players were aged between 17-30 y (mean ± SD; 24.4 ± 3.8 y), and football players were aged between 17-32 y, (25.2 ± 3.8 y). All participants were playing for their respective national teams and competing at international level tournaments at the time of data collection. The number of years playing at an international level varied for both sports and from athlete to athlete. Rugby sevens players ranged between 1-to-6 years of international experience, and football players ranged between 1-to-13 years of international experience. Players provided written consent to participate in competitive matches whilst being monitored and assessed on match performance aspects as part of national team contractual agreements. Participants of this study remain anonymous and will be referred to as players. The study complied with the ethical standards required by Massey University, and the Massey Human Ethics Committee provided ethical approval (4000018800).

VX Log monitoring devices were worn by all rugby sevens players and football players, however data were only used from players that played at least half a match (in terms of minutes of match-play). Therefore, all rugby sevens players that recorded playing 7 min or more and all football players that recorded playing 45 min or more for an individual match were used in this study.

All games across all of the tournaments for rugby sevens and football were played on natural grass. All of the rugby sevens matches took place between 10:00am and 6:00pm local time, with multiple games being played in one day. Six rugby sevens matches were held in USA during March (2017) and played in average temperatures of 18°C (Accu Weather, 2017b). Five rugby sevens matches were held in Japan during April (2017) and played in average temperatures of 15°C (Accu Weather, 2017a). Four rugby sevens matches were held in Canada during May (2017) and played in average temperatures of 16°C (Accu Weather, 2017c). Four football matches took place in Cyprus during March and played in average temperatures of 15°C (Time and Date, 2017). Three of the matches kicked off at 2:30pm local time and the fourth match started at the earlier time of 11:00am local time.

Eighteen players (7 forwards and 11 backs) from one international rugby sevens team were monitored during the mid-season across three legs of the 2016/17 HSBC World Rugby Sevens Series (USA, Japan and Canada). A total number of 15 matches were monitored; six during the USA series, five during the Japan series and four during the Canada series. Nineteen outfield players (7 defenders, 7 midfielders and 5 forwards) from one international football team were monitored during four matches at a pre-season tournament (Cyprus Cup, 2017). Given the known inter- and intra-sport differences in playing positions and positional demands no position-specific data have been presented.

3.2 Equipment and logistics

3.2.1 GPS Units

Match-running output data was collected by GPS (VX Sport, VX Log, Wellington, New Zealand) sampling at 10Hz. All players wore GPS devices (VX Sport, VX Log) in a fitted vest under their playing jersey (Figure 3.1). GPS units were number coordinated to each player and fully charged before each match. Each participant completed the same warm-up routine in their respective sport (rugby sevens or football) prior to kick off for each game. The rugby sevens specific warm-up routine was 7-12 min that included jogging/running, dynamic movements, various passing drills, tackle/contact exercises and explosive footwork. The 30-min football-specific warm-up routine included jogging/running, dynamic movements, a passing and goal-scoring exercise, a possession based game and concluded with explosive sprints. After the warm-up, prior to taking the field for the match, the GPS units were turned on and placed in the back of the fitted vest. The vest is designed to hold the unit securely in place on the back of the participant between the two scapulae. All players had extensive previous experience wearing the GPS units in training and match situations. Monitoring commenced moments before the players took to the field prior to the start of the match and stopped at the end of the match when the players exited the field. The VX Sport System utilised satellite coordinates to convey an outline of the field each match was played on; the data was then overlaid based on the satellite measurements.

Figure 3.1 GPS Fitted Vest (VX Sport, 2018).

3.3 Data Collection

3.3.1 Match Performance

All match-running output data collected from the GPS devices were analysed through the same version of software provided by the manufacturer (VX Sport, VX View software, Wellington, New Zealand).

Match-running output data has been described as total match distance (total metres and metres per minute), distance covered at low-moderate speed (total metres and metres per minute; <16.5 km), distance covered at high speed (total metres and metres per minute; >16.6 km), and sprints (total number and number per minute; >21 km). The speed thresholds represent previously used thresholds in rugby sevens match analysis (Pumpa et al, 2016; Mallo et al, 2015; Higham et al, 2012: Suarez-Arrones et al, 2012), as well as recommended female sport settings (VX View software).

The results of each match played (rugby sevens and football) were not recorded. This introduces other variables that may impact match-running outputs in a non-physical context including tactical play and style of play, and is therefore not considered. However, this may be a consideration worth examining in future studies.

3.4 Statistical Analysis

Statistical analysis was performed using Excel software (Microsoft Office, version 14.7.7). As the data collected on the players in the study had varied competition times (i.e. 14 min games for rugby sevens and 90 min games for football), all results were converted from absolute values to relative values (metres per minute) by dividing the value by the number of minutes the player had played. This allowed the data to be analysed in the same unit of measurement for comparative purposes. The data are presented as means ± SD and statistical significance was accepted at $p<0.05$.

As there was a different number of participant data sets for women's rugby sevens (n = 127) and women's football (n = 33) a homogeneity of variance test was conducted (Levene's test). The homogeneity of variance test conducted (p value: LMSR = <0.01; HSR = <0.01; sprints = <0.01; TD = <0.01) rejected the hypothesis of the variances being the same in rugby sevens and football. Therefore, independent t-Tests assuming unequal variance were conducted to compare between sports.

When looking at the comparisons within the specific-sports, paired (dependent) t-tests were used to compare 1st and 2nd half differences. A one-way analysis of variance (ANOVA), with Tukey post-hoc test used to assess where the difference lay (if required) to compare game-to-game and tournament-to-tournament data.

Additionally, theoretical expected match-running outputs were estimated from international male rugby sevens players (Ross, Gill & Cronin, 2015a) and international male football players (Mallo et al, 2015). The means from the rugby sevens data used (forwards and backs) were averaged and the standard deviations pooled (Pooled Variance Calculator, 2018). Using the data (mean ± SD) from the results of this study and comparing against the existing male research enabled comparative analysis between female and male rugby sevens players, and female and male football players. The men's rugby and football data were converted into relative values (metres per minute) as described above.

Effect size was calculated (Becker, 2000) for male and female rugby sevens data and male and female football data. Effect size cut-offs were based on Cohen's d value (Becker, 2000); small (0.2), medium (0.5) or large (0.8). The following formula was used to calculate all percentage differences:

Percentage difference = $|Y_1 – Y_2|/((Y_1+Y_2)/2) \times 100$
Where Y indicates mean (e.g. male mean – female mean)

Chapter 4

RESULTS

4.0 Rugby Sevens and Football

This section presents the data collected from the 18 female rugby sevens players and 19 female football players. In a 14-min game, female rugby sevens players (n = 127 data sets) and in a 90-min game, female football players (n = 33 data sets) recorded match-running outputs which are presented in metres per minute; low-to-moderate speed running (LMSR), high speed running (HSR), total distance (TD) and in number per minute for sprints in Table 4.1. Also presented (Table 4.2) is the men's rugby sevens (Ross, Gill & Cronin, 2015a) and football (Mallo et al, 2015) data used for sex comparisons. For sex and sport comparison purposes, the results from the current study and the studies used for male comparisons (rugby sevens; Ross, Gill & Cronin, 2015a and football; Mallo et al, 2015) have been further broken down (total metres and total no. / total min) into metres per minute and number per minute in the following sections; LMSR, HSR, TD and sprints.

Table 4.1 14 min and 90 min female match-running outputs (rugby sevens and football)

Sport		Low-to-moderate speed running ($m \cdot min^{-1}$)	High speed running ($m \cdot min^{-1}$)	Total Distance ($m \cdot min^{-1}$)	Sprints (no.·min)
Rugby sevens	Mean and SD	43.3 ± 19.8	6.3 ± 5.7	49.8 ± 23.6	0.2 ± 0.3
	Number of data sets	127	127	127	127
Football	Mean and SD	89.5 ± 10.9	3.25 ± 2.8	93 ± 10.4	2.5 ± 0.5
	Number of data sets	33	33	33	33

*SD = standard deviation *$m \cdot min^{-1}$ = metres per minute *no.·min = number per minute.

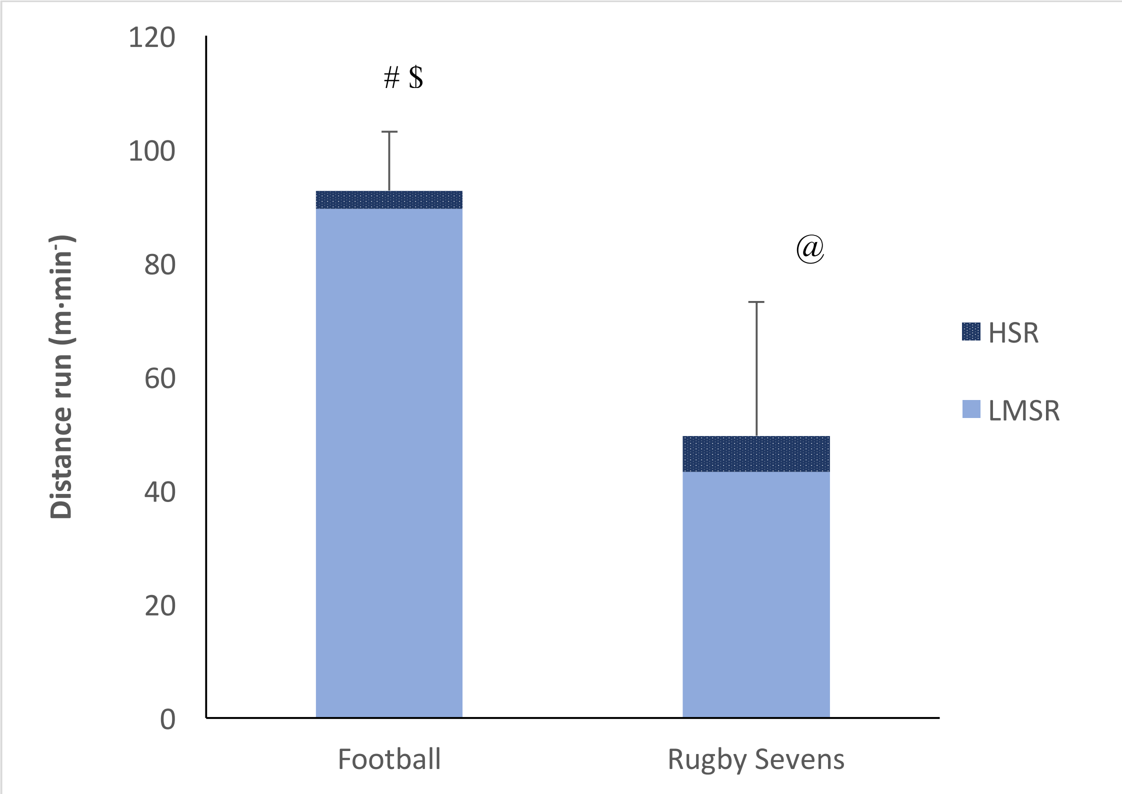
Table 4.2 14 min and 90 min male match-running outputs; rugby sevens (Ross, Gill & Cronin, 2015a) and football (Mallo et al, 2015)

Sport		Low-to-moderate speed running ($m \cdot min^{-1}$)	High speed running ($m \cdot min^{-1}$)	Total Distance ($m \cdot min^{-1}$)	Sprints (no.·min)
Rugby sevens	Mean and SD	84.8 ± 17.4	17.9 ± 8.4	102.6 ± 20.5	0.6 ± 0.1
	Number of data sets	27	27	27	27
Football	Mean and SD	91.6 ± 4.8	24.0 ± 3.6	119.9 ± 12.8	4.3 ± 2.5
	Number of data sets	111	111	111	111

*SD = standard deviation *$m \cdot min^{-1}$ = metres per minute *no.·min = number per minute.

4.1 Female Match-Running Output Comparison

Female rugby sevens players completed fewer LMSR running metres than female football players (rugby sevens = 43.3 ± 19.8 $m \cdot min^{-1}$ vs. football = 89.5 ± 10.9 $m \cdot min^{-1}$, t(93) = -18.02, p<0.01, d = -2.96, Figure 4.1). Female rugby sevens players completed more HSR running metres then female football players (rugby sevens = 6.3 ± 5.7 $m \cdot min^{-1}$ vs. football = 3.25 ± 2.8 $m \cdot min^{-1}$, t(108) = 4.37, p<0.01, d = 0.7, Figure 4.1). Female rugby sevens players completed fewer TD running metres than female football players (rugby sevens = 49.8 ± 23.6 $m \cdot min^{-1}$ vs. football = 93 ± 10.4 $m \cdot min^{-1}$, t(121) = -15.69, p<0.01, d = -1.1, Figure 4.1). Female rugby sevens players performed fewer sprints than female football players (rugby sevens = 0.2 ± 0.3 no.·min vs. football = 2.5 ± 0.5 no.·min, t(38) = -24.73, p<0.01, d = -5.6).



*LMSR = low-to-moderate speed running *HSR = high speed running *m·min^{-1} = metres per minute *# = significant difference *@ = significant difference *$ = significant difference

Figure 4.1 Distance covered by women rugby sevens and women football players; mean ± SD for total distance (TD), comprising of low-to-moderate speed running (LMSR; m·min^{-1}) and high speed running (HSR; m·min^{-1}). # significantly higher LMSR than rugby sevens, $p<0.01$, @ significantly higher HSR than football, $p<0.01$, $ significantly higher TD than rugby sevens, $p<0.01$.

4.2 Female vs. Male Match-Running Output Comparison

Male rugby sevens players (Ross, Gill & Cronin, 2015a) completed more metres in LMSR compared to female rugby sevens players (male = 84.8 ± 17.4 m·min^{-1} vs. female = 43.3 ± 19.8 m·min^{-1}, $t(152) = 10.9$, $p<0.01$, $d = 2.4$), a 64.8% difference. Male football players (Mallo et al, 2015) and female football players performed at a similar level in LMSR (male = 91.6 ± 4.8 m·min^{-1} vs. female = 89.5 ± 10.9 m·min^{-1}, $t(142) = 1.08$, $p = 0.28$, $d = 0.4$) a 2.3% difference.

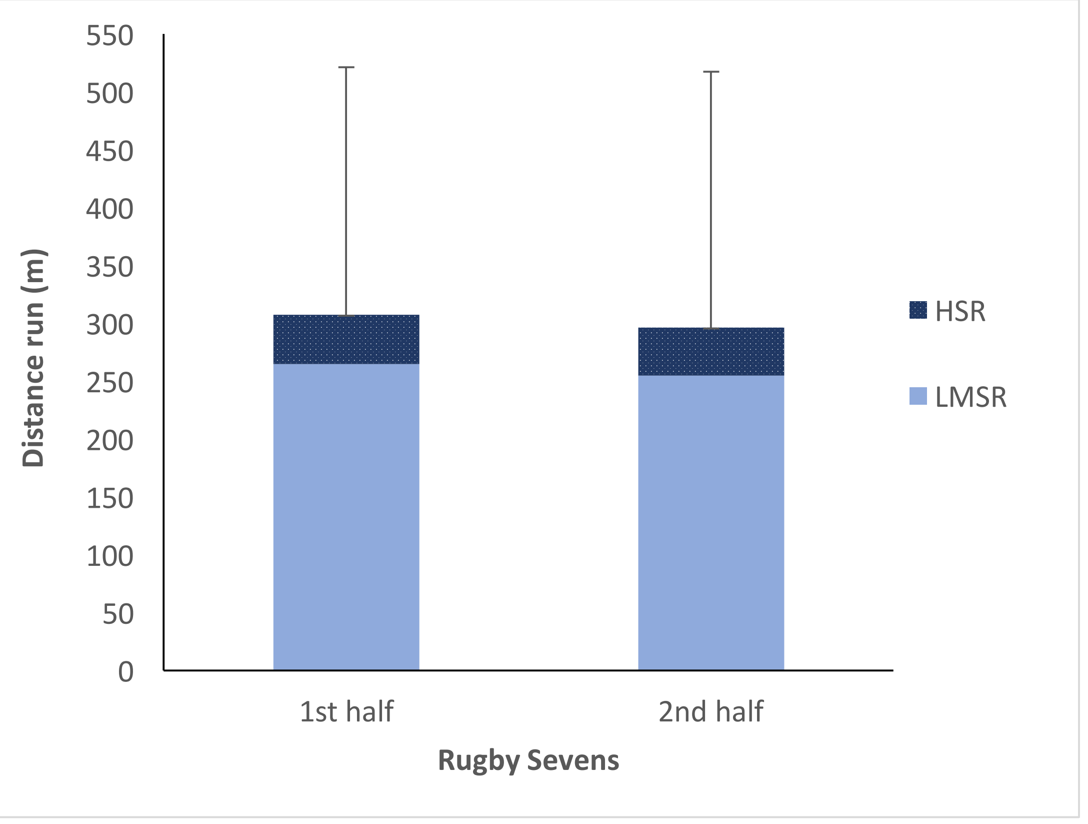
Male rugby sevens players (Ross, Gill & Cronin, 2015a) completed more metres in HSR compared to female rugby sevens players (male = 17.9 ± 8.4 $m \cdot min^{-1}$ vs. female = 6.3 ± 5.7 $m \cdot min^{-1}$, t(152) = 6.8, p<0.01, d = 1.5) a 95.9% difference. Male football players (Mallo et al, 2015) completed more metres in HSR compared to female football players (male = 24.0 ± 3.6 $m \cdot min^{-1}$ vs. female = 3.25 ± 2.8 $m \cdot min^{-1}$, t(142) = 34.9, p<0.01, d = 6.3) a 152.3% difference.

Male rugby sevens players (Ross, Gill & Cronin, 2015a) completed more metres in TD (LMSR + HSR = TD) compared to female rugby sevens players (male = 102.6 ± 20.5 $m \cdot min^{-1}$ vs. female = 49.8 ± 23.6 $m \cdot min^{-1}$, t(152) = 11.8, p<0.01, d = 1.6) a 69.3% difference. Male football players (Mallo et al, 2015) completed more metres in TD compared to female football players (male = 119.9 ± 12.8 $m \cdot min^{-1}$ vs. female = 93 ± 10.4 $m \cdot min^{-1}$, t(142) = 12.3, p<0.01, d = 1.9) a 25.3% difference.

Male rugby sevens players (Ross, Gill & Cronin, 2015a) performed more sprints compared to female rugby sevens players (male = 0.6 ± 0.1 no.·min vs. female = 0.2 ± 0.3 no.·min, t(152) = 12.1, p<0.01, d = 1.6) a 100% difference. Male football players (Mallo et al, 2015) performed more sprints compared to female football players (male = 4.3 ± 2.5 no.·min vs. female = 2.5 ± 0.5 no.·min, t(142) = 7.1, p<0.01, d = 0.998) a 52.9% difference.

4.3 1st Half vs. 2nd Half Female Match-Running Output Comparison

Figure 4.2 represents the 1st and 2nd half female rugby sevens data for tournament 1 and 2 in total metres for LMSR (1st half = 264.5 ± 180.54 m vs. 2nd half = 254.6 ± 189.45 m). There was no difference between total distance covered in each half (t(87) = 1.12, p = 0.26). There was no difference between total distance covered in each half (t(87) = 1.12, p = 0.26) for HSR (1st half = 42.8 ± 50.7 m vs. 2nd half = 41.6 ± 46.47 m). There was no difference between total distance covered in each half (t(87) = 1.07, p = 0.29) for TD (1st half = 307.8 ± 214.14 m vs. 2nd half = 296.2 ± 220.99 m). (1st half = 1.9 ± 2.48 no. vs. 2nd half = 1.9 ± 2.01 no.), there was no difference between total number of sprints performed in each half (t(87) = 0.58, p = 0.56). Due to technical difficulties during one tournament the GPS data could not be separated into discrete halves and so the above results are representative of n=10 data sets.

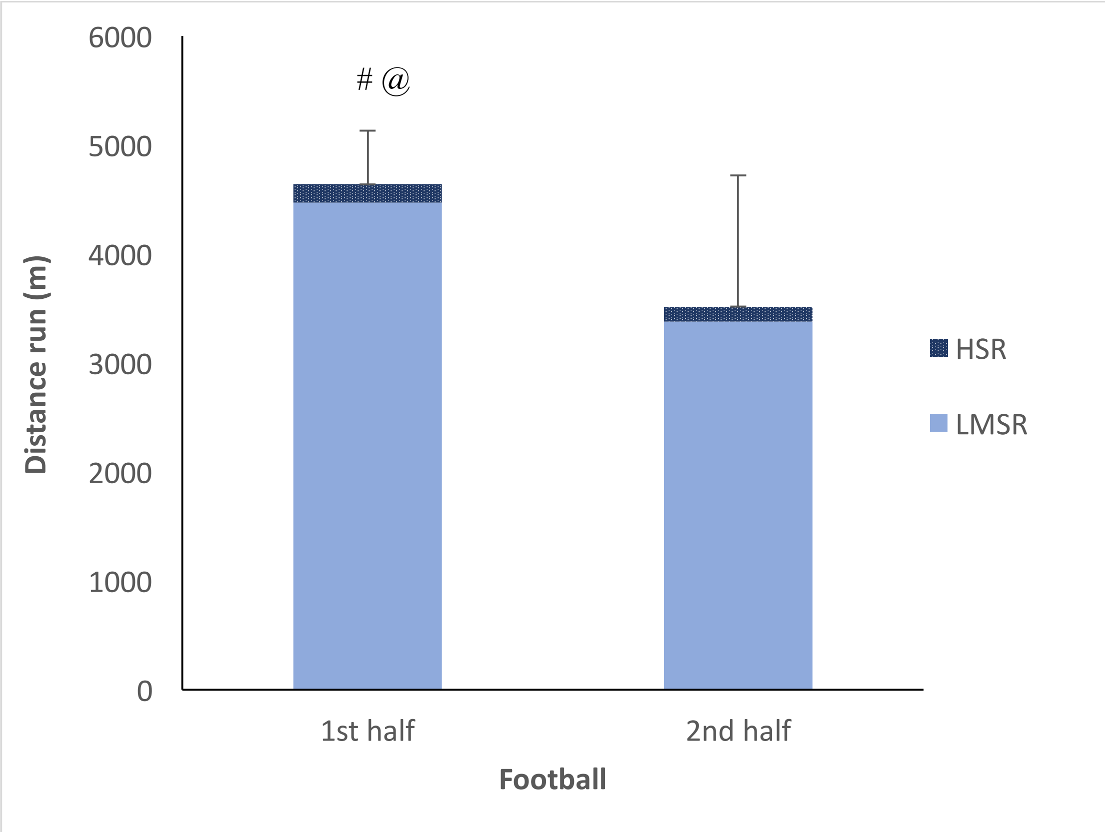


*LMSR = low-to-moderate speed running *HSR = high speed running *m = metres

Figure 4.2 1st half vs. 2nd half distance covered by women rugby sevens players; mean ± SD for total distance (TD), comprising of low-to-moderate speed running (LMSR; m) and high speed running (HSR; m).

Figure 4.3 represents the data for the 1st and 2nd halves for female football. Players performed greater LMSR in the first half compared to the second half (1st half = 4473.78 ± 526.9 m vs. 2nd half = 3376.13 ± 1172.7 m; $t(32) = 5.65$, $p<0.01$). There was no difference between total distance covered in each half ($t(32) = 1.35$, $p = 0.19$) for HSR (1st half = 167.78 ± 142.1 m vs. 2nd half = 140.45 ± 143.2 m). There was a difference between total distance covered in each half ($t(32) = 5.55$, $p<0.01$) for TD (1st half = 4641.57 ± 490.4 m, 2nd half = 3516.58 ± 1205.3 m). (1st half = 130.87 ± 22.9 no.

vs. 2nd half = 89.89 ± 33.1 no.), there was a difference between total number of sprints performed in each half ($t(32) = 6.45$, $p<0.01$).



*LMSR = low-to-moderate speed running *HSR = high speed running *m = metres *# = significant difference *@ = significant difference

Figure 4.3 1st half vs. 2nd half distance covered by women football players; mean ± SD for total distance (TD), comprising of low-to-moderate speed running (LMSR; m) and high speed running (HSR; m). # significantly higher LMSR than 2nd half, $p<0.01$, @ significantly higher TD than 2nd half, $p<0.01$.

4.4 Game and Tournament Match-Running Output Comparison

4.4.1 Football

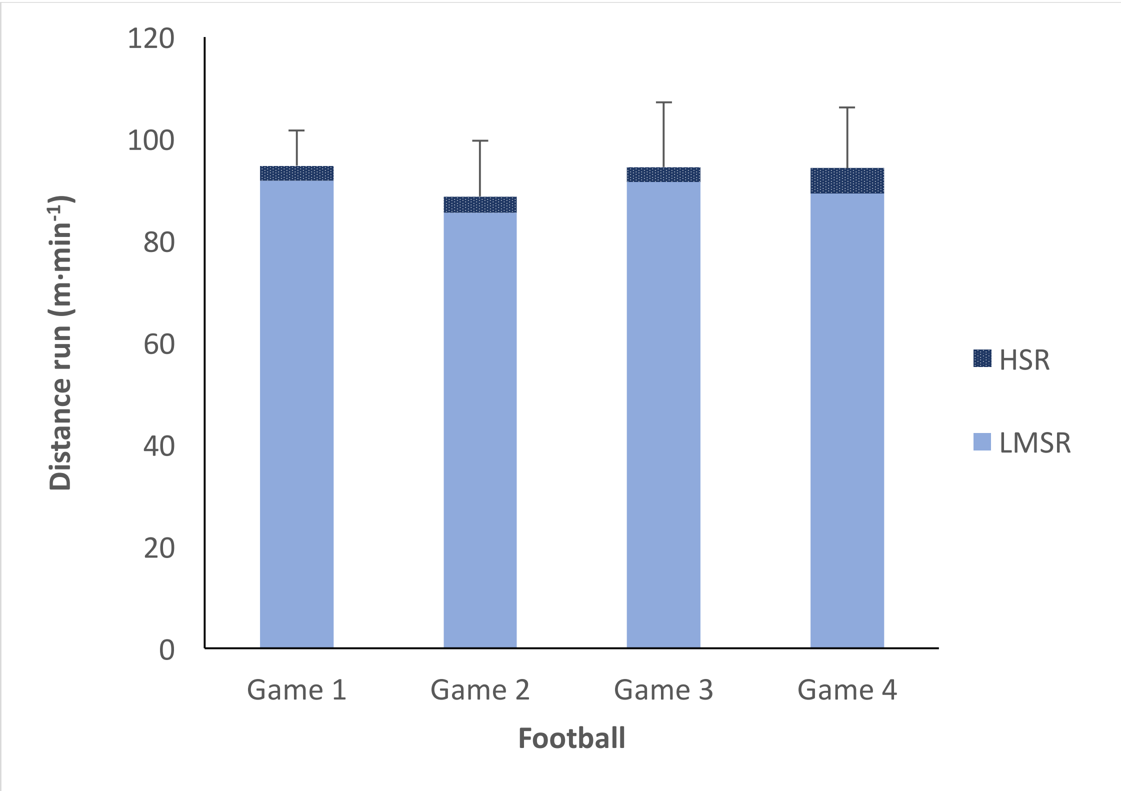
Table 4.3 presents the means and SD for LMSR, HSR, sprints and TD for the women's football match-running output data collected in each game (four) of the tournament.

Table 4.3 Women's football match-running outputs (low-to-moderate speed running, LMSR; high speed running, HSR; total distance, TD; and sprints) means ± SD for each game.

	LMSR ($m \cdot min^{-1}$)	HSR ($m \cdot min^{-1}$)	Sprints ($no. \cdot min^{-1}$)	TD ($m \cdot min^{-1}$)
Game 1	91.73 ± 6.87	2.92 ± 1.42	2.6 ± 0.41	94.67 ± 7.02
Game 2	85.46 ± 10.54	3.22 ± 1.37	2.25 ± 0.54	88.66 ± 10.91
Game 3	91.46 ± 12.08	2.96 ± 1.94	2.74 ± 0.59	94.45 ± 12.69
Game 4	89.28 ± 14.99	4.97 ± 5.23	2.59 ± 0.46	94.26 ± 11.87
Sig. diff.	0.64	0.44	0.27	0.61

*LMSR = low-to-moderate speed running *HSR = high speed running *TD= total distance *$m \cdot min^{-1}$ = metres per minute *no.·min = number per minute *Sig. diff. = significant difference.

Figure 4.4 represents the female football game data in relative terms ($m \cdot min^{-1}$). There was no difference in LMSR between each of the matches ($F(3,29) = 0.57$, $p = 0.64$). There was no difference in HSR ($F(3,29) = 0.93$, $p = 0.44$), TD ($F(3,29) = 0.61$, $p = 0.61$), or sprints performed ($F(3,29) = 1.36$, $p = 0.27$) between each of the matches.



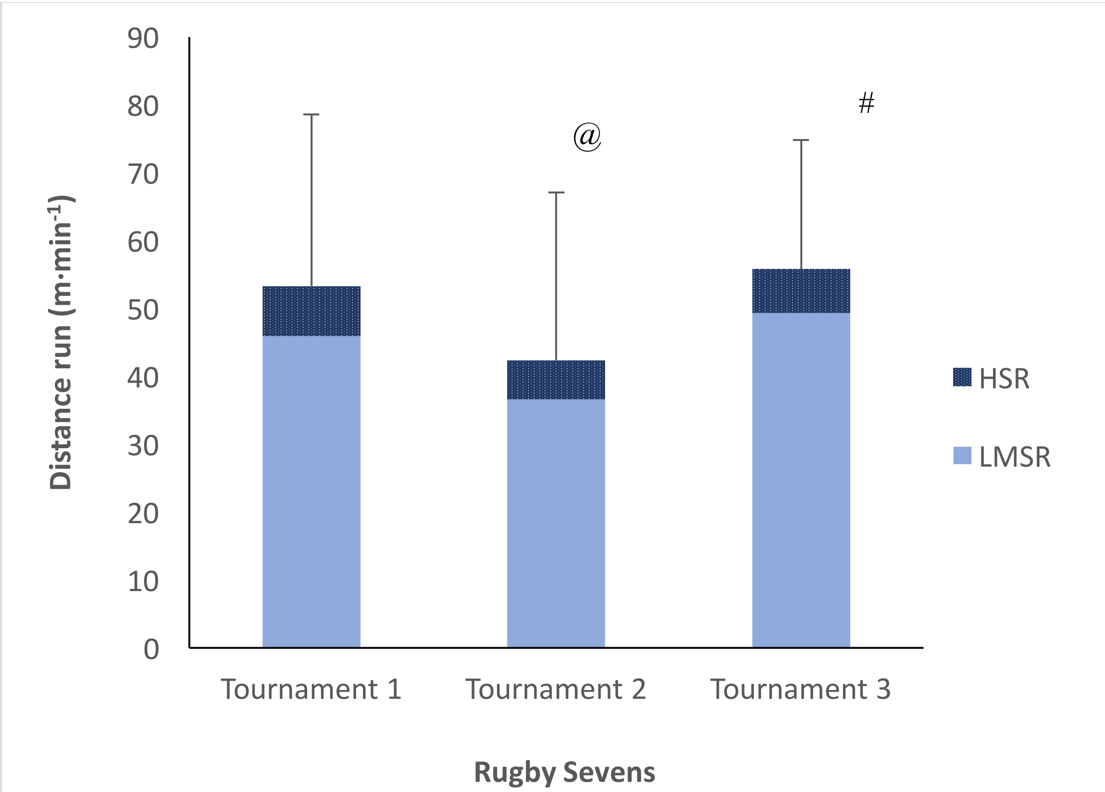
*LMSR = low-to-moderate speed running *HSR = high speed running *m·min^{-1} = metres per minute

Figure 4.4 Game vs. game distance covered by women football players; mean ± SD for total distance (TD), comprising of low-to-moderate speed running (LMSR; m·min^{-1}) and high speed running (HSR; m·min^{-1}).

4.4.2 Rugby Sevens

Figure 4.5 represents female rugby sevens tournament data in relative terms (m·min^{-1}). There was a difference in LMSR (tournament 1 = 45.93 ± 21.7 m·min^{-1}, tournament 2 = 36.59 ± 19.8 m·min^{-1}, tournament 3 = 49.31 ± 2 m·min^{-1}, $F(2,124) = 73.5$, $p<0.01$), and post-hoc analysis revealed the differences were between tournament 2 and tournament 3 ($p<0.05$), and between tournament 3 and tournament 1 ($p <0.05$). There was also a difference in number of sprints (tournament 1 = 0.23 ± 0.3 no.·min^{-1}, tournament 2 =

0.37 ± 0.3 no.·min^{-1}, tournament 3 = 0.09 ± 0.1 no.·min^{-1}, $F(2,123) = 13.5$, $p<0.01$), and post-hoc analysis revealed the differences were between tournament 1 and tournament 2 ($p<0.05$), and between tournament 2 and tournament 3 ($p<0.05$). There was no difference in HSR between tournaments (tournament 1 = 7.36 ± 5.5 m·min^{-1}, tournament 2 = 5.78 ± 6.7 m·min^{-1}, tournament 3 = 6.48 ± 4.2 m·min^{-1}, $F(2,123) = 0.19$, $p = 0.82$), or TD between tournaments (tournament 1 = 53.39 ± 25.3 m·min^{-1}, tournament 2 = 42.36 ± 24.7 m·min^{-1}, tournament 3 = 55.79 ± 18.98 m·min^{-1}, $F(2,123) = 2.89$, $p = 0.06$).



*LMSR = low-to-moderate speed running *HSR = high speed running *m·min^{-1} = metres per minute *# = significant difference *@ = significant difference

Figure 4.5 Tournament vs. tournament distance covered by women rugby sevens players; mean ± SD for total distance (TD), comprising of low-to-moderate speed running (LMSR; m·min^{-1}) and high speed running (HSR; m·min^{-1}). @ significantly lower LMSR than tournament 3, $p<0.05$, # significantly higher LMSR than tournament 1, $p<0.05$.

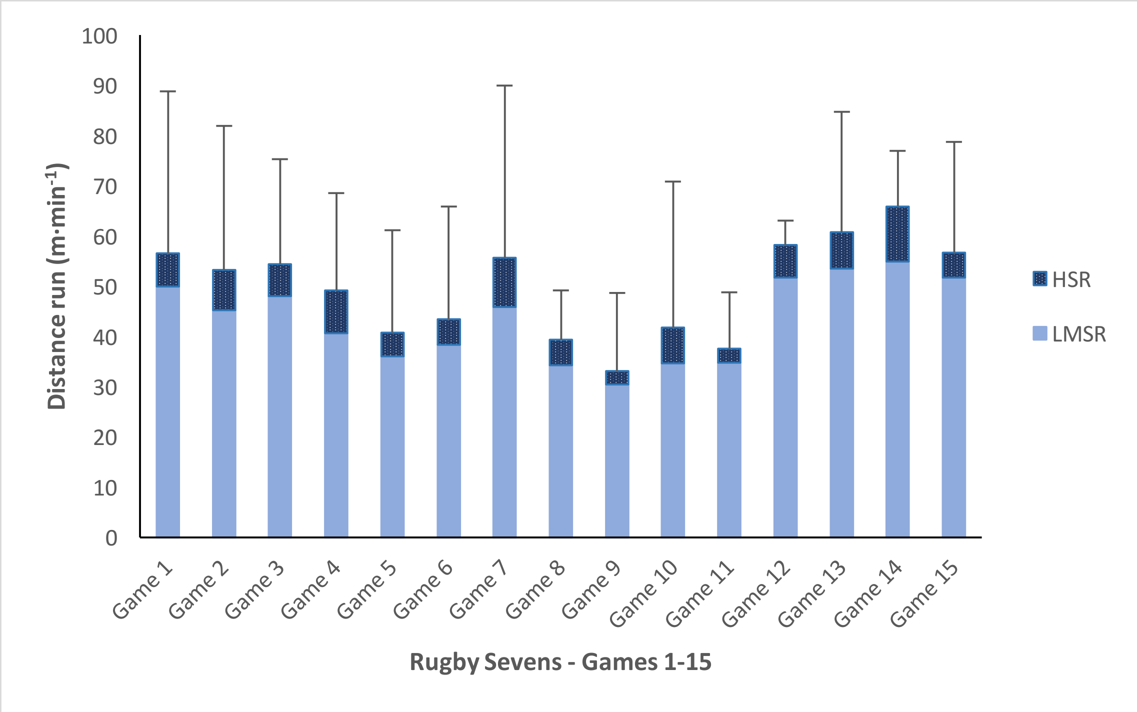
Table 4.4 presents the means and SD for LMSR, HSR, sprints and TD for the women's rugby sevens match-running performance data collected in each game (15) across the three tournaments.

Table 4.4 Women's rugby sevens match-running outputs (LMSR, HSR, sprints and TD) means ± SD for each game.

	LMSR ($m \cdot min^{-1}$)	HSR ($m \cdot min^{-1}$)	Sprints ($no. \cdot min^{-1}$)	TD ($m \cdot min^{-1}$)
Game 1	49.88 ± 28.12	6.67 ± 5.81	0.21 ± 0.2	56.56 ± 32.24
Game 2	45.26 ± 22.14	7.69 ± 7.78	0.14 ± 0.15	53.61 ± 28.65
Game 3	47.96 ± 20.39	6.43 ± 3.52	0.39 ± 0.5	54.29 ± 20.89
Game 4	40.62 ± 16.36	8.48 ± 6.2	0.17 ± 0.14	49.09 ± 19.46
Game 5	35.01 ± 16.31	4.78 ± 4.64	0.36 ± 0.32	40.77 ± 20.29
Game 6	38.31 ± 21.65	5.16 ± 4.4	0.36 ± 0.27	42.18 ± 22.34
Game 7	45.86 ± 26.41	9.81 ± 10.68	0.45 ± 0.5	55.68 ± 34.33
Game 8	34.25 ± 9.64	5.12 ± 3.68	0.33 ± 0.15	39.37 ± 9.74
Game 9	30.47 ± 14.12	2.63 ± 2.08	0.23 ± 0.22	33.09 ± 15.49
Game 10	34.61 ± 21.71	7.13 ± 6.17	0.48 ± 0.36	43.06 ± 29.02
Game 11	34.74 ± 9.88	2.82 ± 2.09	0.04 ± 0.56	37.56 ± 11.24
Game 12	51.69 ± 4.76	6.46 ± 1.18	0.06 ± 0.07	58.15 ± 4.93
Game 13	53.49 ± 20.96	7.25 ± 4.13	0.15 ± 0.09	60.73 ± 24
Game 14	54.92 ± 8.78	10.97 ± 3.14	0.1 ± 0.07	65.89 ± 11.07
Game 15	51.71 ± 18.49	4.92 ± 4.69	0.09 ± 0.13	56.63 ± 22.1
Sig. diff.	0.16	0.12	0.003	0.16

*LMSR = low-to-moderate speed running *HSR = high speed running *TD= total distance *$m \cdot min^{-1}$ = metres per minute *no.·min = number per minute *Sig. diff. = significant difference.

Figure 4.6 represents the female rugby sevens game data in relative terms ($m \cdot min^{-1}$). There was no difference in LMSR ($F(14,111) = 1.39$, $p = 0.16$), HSR ($F(14,111) = 1.50$, $p = 0.12$) or TD ($F(14,111) = 1.42$, $p = 0.16$) between each of the matches. However, there was a difference in number of sprints ($F(14,111) = 2.56$, $p<0.01$), and post-hoc analysis revealed the differences were between game 7 and game 11 ($p<0.05$).



*LMSR = low-to-moderate speed running *HSR = high speed running *m·min^{-1} = metres per minute

Figure 4.6 Game vs. game distance covered by women rugby sevens players; mean ± SD for total distance (TD), comprising of low-to-moderate speed running (LMSR; m·min^{-1}) and high speed running (HSR; m·min^{-1}).

Chapter 5

DISCUSSION

The primary purpose of the current study was to observe the match-running outputs of international female rugby sevens players and international female football players to contextualise against each other, and against theoretical expected match-running outputs. The current study explores the sex performance gap for both sports and between sports in order to generate theoretical expected performance benchmarks. The known and quantified physiological difference in performance levels between elite male and female athletes (5-12%), (Thibault et al, 2010; Haugen et al, 2017), is the percentage difference used to judge theoretical expected performance measures for female and male players across both sports (rugby sevens and football). Where differences in performance occurs for female rugby sevens players and female football players, possible reasons for the differences are determined. This study is unique as it uses rare elite (international) female and male athlete data across both sports allowing confident use of the comparisons and results at an elite level.

5.0 Female Rugby Sevens and Female Football Match-Running Outputs

Female football players performed more LMSR and TD metres and more sprints compared to female rugby sevens players, while female rugby sevens players performed more HSR metres compared to female football players (Figure 4.1). Excluding the HSR results, these findings were similar to previous rugby sevens and football research. Previous research studies (Krustrup et al, 2005; Bradley et al, 2014; Pumpa et al, 2016) show that female football players complete more metres in LMSR, HSR and TD than female rugby sevens players (Vescovi & Goodale, 2015; Clarke, Anson & Pyne, 2014), while there was no comparable data on sprint performance. A possible reason for these results could be an established sport versus an emerging sport. Women’s football is the most popular female sport in the world with 30 million female (girls/women) players (FIFA, 2015b). Women’s rugby sevens (inclusive of rugby union), is considered an emerging sport and is estimated to have 2 million female players, 28 million fewer than women's football (World Rugby, 2016e). The first World Cup for women's football was played in 1991 (FIFA, 2016), 18 years before the first women's rugby seven's World Cup. Therefore, ability and performance levels of female football players may be higher due to greater training and/or game experience (Goodale et al, 2016). Success at an elite level can be linked to grassroots participation in sports (Jacobs, 2014; Pederson & Seidman, 2004) as accumulative years of playing from a younger age improves physical and psychological outcomes for adolescents and adults (Pederson & Seidman, 2004).

Unexpected differences observed in HSR results compared to previous research studies (Krustrup et al, 2005; Bradley et al, 2014; Pumpa et al, 2016; Vescovi & Goodale, 2015; Clarke, Anson & Pyne, 2014), showing that female rugby sevens players performed more HSR metres, could be due to the differences in characteristics of the two sports and low recordings in HSR for female football players. The differences in characteristics between rugby sevens and football specifically include fewer player numbers, and ball carrying occurring in the hands rather than at the feet (Dziedzic & Higham, 2014; Higham et al, 2012). Rugby sevens and football are played on similar size pitches, however rugby sevens consist of 7 outfield players and football 10 outfield players (plus a goalkeeper). The significantly reduced number of players in rugby sevens was designed primarily to speed up the game (World Rugby, 2009). Fewer players on the field means there are fewer obstacles to overcome, more time to reach higher running speeds, as well as larger spaces to attack at higher running speeds (Gabbett, 2006). Ball carrying occurring in the hands (rugby sevens) rather than at the feet (football) allows players to run at higher speeds for a longer time (Forbes, 2013).

Female football HSR results could be attributed to low recordings when compared with previously reported data (Krustrup et al, 2005; Bradley et al, 2014; Pumpa et al, 2016), due to tactical play (style/formations) and time of season (pre-season/mid-season/post-season). Tactical play can impact match-running outputs as players may be required to defend and attack in ways that require less or more running (Ortega et al, 2007). Time of season may mean players are in different phases of training; pre-season players building fitness levels, mid-season players are maintaining fitness levels and accumulating match fitness, and post-season players could be in a downloading phase allowing their bodies to repair (Rampinini et al, 2007). Pre-season data was utilised for the current study, whereas the previous studies (Krustrup et al, 2005; Bradley et al, 2014; Pumpa et al, 2016) collected data during mid-season, which showed higher HSR results.

Rugby sevens players have a far shorter duration per match (14 min) and therefore play under less fatigue than football players with a match duration of 90 min. Therefore, comparing rugby sevens to football standards might be seen as a reach, however using the elite female football data to establish a sex performance gap between elite male and female football players gives a more comparable standard that eliminates the restricting differences between the sports.

5.1 Female vs. Male Rugby Sevens Match-Running Outputs

Comparing the female rugby sevens players' data against the current literature on male rugby sevens players **(**Ross, Gill & Cronin, 2015a), whilst considering the established sex performance gap of 5-12% (Thibault et al, 2010; Haugen et al, 2017), shows an anomaly between each of the four match-running output measures (LMSR, HSR, TD and sprints). This is consistent with previous research (Ross, Gill & Cronin, 2015a; Rienzi, Reilly & Malkin, 1999; Suarez-Arrones et al, 2012) that showed male rugby sevens players perform more LMSR, HSR and TD metres as well as more sprints than female rugby sevens players (Vescovi & Goodale, 2015; Clarke, Anson & Pyne, 2014).

Differences in physiology between males and females such as testosterone levels, body size, muscle mass/strength/power and bone density (Crewther, Obminski & Cook, 2016) could contribute to the results. Androgenic hormones have performance-enhancing effects, specifically on strength, power and speed providing a competitive advantage in sports and between males and females (Muller, 2016; Caplan & Parent, 2017). Males are typically larger than females, possessing greater bone density and muscle mass (Rigby & Kulathinal, 2015; Crewther, Obminski & Cook, 2016).

Increased muscle mass and increased strength and power aids sporting performance by increasing an athlete's aerobic endurance, anaerobic endurance, speed, physical strength and explosiveness, impacting match-running outputs (Barr et al, 2014; Nicolo et al, 2014; Robinson et al, 2014; Hottenrott, Ludyga & Schulze, 2012; Simao et al, 2012; Iaia & Bangsbo, 2010; Hori et al, 2008; Cronin & Hansen, 2005). It is important to note that the current study focused on measuring and comparing elite level athletes' match-running outputs, and did not measure and compare hormonal status or body composition.

Individual male rugby sevens players may have also played at an elite/professional level for a longer period of time compared to the female rugby sevens players, thus impacting results. The first rugby sevens world cup for men was held in 1993, 16 years before the first women's rugby sevens world cup (World Rugby, 2016b). Therefore, male rugby sevens players have had greater opportunity to play at an elite level and may possess greater ability and performance levels due to greater training and/or game experience (Goodale et al, 2016).

Despite the large sex performance gap between male and female rugby sevens players, researchers have highlighted a rapid rate of performance gains in female athletes' relative to male athletes' over recent years (Tatem et al, 2004). A key variable contributing to the performance growth rate seen in female athletes across major sports (football, athletics, tennis, golf, basketball, hockey and netball) is the recent increase in professionalism. Professionalism generally attained from increased funding resulting in greater player education and support in areas such as coaching, nutrition, physical education, injury prevention awareness and mental stability. These benefits provide female athletes with the ability to take responsibility in maintaining physical fitness and up-holding higher performance standards. There are non-physical reasons that may contribute to the performance gaps found, but further exploration of these factors is outside the scope of the thesis.

One specific example of an amateur activity becoming a professional discipline in a short period of time, is the women's pole vault. The women's pole vault became a part of the IAAF World Championships in 1999, and made its first appearance at the Sydney 2000 Olympic Games (IAAF, 2018a). The women's WR in 2000 stood at 4.60 m and has since been broken multiple times and now stands at 5.06 m (IAAF, 2018b), while the men's 2000 WR stood at 6.14 m and the current WR is 6.16 m (IAAF, 2018c). The women have shown a greater rate of performance growth compared to the men and now have a sex performance gap of 1.10 m or 19.6%. However, when considering the variables of why this is occurring, performance gain trends for females should slow down and settle into a similar growth rate to males. Known physiological differences between males and females will be a key contributor in restricting the extent that female performance is able to reach (Tatem et al, 2004).

5.2 Female vs. Male Football Match-Running Outputs

Comparing the female football players' data collected against the current literature on male football players (Mallo et al, 2015), whilst considering the established sex performance gap of 5-12% (Thibault et al, 2010; Haugen et al, 2017), shows an anomaly between three of the match-running output measures (HSR, TD and sprints). However, LMSR performance was similar, correlating with the expected performance sex gap. Previous studies (Krustrup et al, 2005; Bradley et al, 2014; Pumpa et al, 2016) showed female football players match-running outputs to be within or closer to the expected sex gap of 5-12% in LMSR, TD and HSR (there was no comparable sprint data).

The observed results may be due to the differences in physiology between males and females, and male football players playing at an elite/professional level for a longer period of time. HSR specifically, as well as TD and sprints, could also be attributed to lower recordings for female football players, due to tactical play (style/formations) and/or time of season (pre-season/mid-season/post-season) (Ortega et al, 2007; Rampinini et al, 2007). There may also be inconsistencies between GPS devices used across the different studies on female football players (Krustrup et al, 2005; Bradley et al, 2014; Pumpa et al, 2016) compared to the methods employed and GPS devices used in this thesis. Reliability of GPS devices varies as brands and sampling frequency (Hertz) differ (Johnston et al, 2014; Cummins et al, 2013). GPS devices sampling at 10 Hz and 15 Hz are considered the most reliable and accurate GPS devices in comparison to GPS devices sampling at 1 Hz and 5 Hz (Johnston et al, 2014).

5.3 Sex Comparison of Match-Running Outputs between Rugby Sevens and Football

When examining the observed sex performance gaps between rugby sevens and football, the established sport (football) is closer to the established sex performance gap of 5-12% (Thibault et al, 2010; Haugen et al, 2017) across three of the four match-running output measures (LMSR, TD and sprints) as shown in Table 5.1.

Table 5.1 Sex performance gap percentage (%) for rugby sevens and football

	LMSR	HSR	TD	Sprints
Rugby Sevens	64.8%	95.9%	69.3%	100%
Football	2.3%	152.3%	25.3%	52.9%

*LMSR = low-to-moderate speed running *HSR = high speed running *TD = total distance

The LMSR sex performance gap observed for football of 2.3% is slightly better than the established sex expectations of elite female and male athletes (5-12%; Thibault et al, 2010; Haugen et al, 2017). However, the sex performance gaps observed in TD, HSR and sprints are larger than what is expected for an established sport, especially when compared to previous research (Krustrup et al, 2005; Bradley et al, 2014; Pumpa et al, 2016. The major reason considered for the unexpected results for the sex performance gap between footballers is seasonality as the data collected for this study was collected during a pre-season tournament and not mid-season. Players are developing and building their fitness levels during the pre-season phase, whereas players are at their peak performance level during the mid-season phase (Rampinini et al, 2007).

The results observed in LMSR, TD and sprints suggests that female rugby sevens players have a considerable amount of room for development in these specific aspects of match-running outputs when compared to the sex performance gap observed between football players, and the established sex performance gap of 5-12%. This could be due to women's rugby sevens being an emerging sport and therefore lacking depth, and players going from an amateur level to professional level in a relatively short period. Due to these factors female rugby sevens players' training and game experience may be lower (Goodale et al, 2016). In 19 years as an elite female sport, the women's pole vault has reduced the sex performance gap from 28.7% to 19.6%. Women's rugby sevens, considered an elite sport for nine years, presents itself with an opportunity for great performance growth across all match-running output measures (LMSR, HSR, TD and sprints).

Football showed a larger gap of 152.3% in HSR, while rugby sevens showed a gap of 95.9%, contrary to expectations, the emerging sport (rugby sevens) was closer to the established sex performance gap than the established sport (football). The observed findings of HSR were different when compared to previous research (Krustrup et al, 2005; Bradley et al, 2014; Pumpa et al, 2016) that showed female football players perform more HSR metres than female rugby sevens players (Vescovi & Goodale, 2015; Clarke, Anson & Pyne, 2014). Possible reasons for this have been discussed throughout this section and may be specifically attributed to lower recordings in HSR for female football players.

An important factor to consider could be that the established sex performance gap established from track and field athletics world records of 5-12% (Thibault et al, 2010; Haugen et al, 2017) may be too low for team-based sports that require players to run at different speeds and incorporate a wide range of different skills (Nicholas, 1997; Di Mascio & Bradley, 2013). The match demands of rugby sevens and football are characterised by the complex nature that requires elite players to have well-developed overall physical fitness qualities, the ability to execute technical skills and employ tactical decisions (Meir, 2012; Duthie, Pyne & Hooper, 2003). Performance measures may be easier to compare between two team sports as opposed to a team sport and an individual sport. However, there are many differences between rugby sevens and football that may affect results and comparisons.

5.3 Female 1st Half vs. 2nd Half Match-Running Outputs

5.3.1 Football

There was no difference between 1st and 2nd half HSR performance in football players, however, there was a difference in LMSR, with players covering more distance in the 1st half than the 2nd half (Figure 4.3). Therefore, players covered greater TD in the 1st half than the 2nd half, and also performed more sprints in the 1st half. It would be expected that the HSR results aligned with the LMSR, TD and sprint results, which are similar to previous research showing that elite football players match-running outputs decrease towards the end of a game due to fatigue (Barte et al, 2017; Djaoui et al, 2017; Krustrup et al, 2010; Mohr et al, 2008). More specifically, elite footballers experience fatigue at three different stages of a game; after short intense periods, at the start of the second half, and towards the end of the game (Mohr, Krustrup & Bangsbo, 2005). Fatigue occurs due to several possible reasons including depleted glycogen levels, lactate accumulation, muscle temperatures, dehydration and reduced cerebral function (Mohr, Krustrup & Bangsbo, 2005). This could contribute to the decrease in LMSR, TD and number of sprints performed from 1st half to 2nd half.

5.3.2 Rugby Sevens

The women's rugby sevens 1st half vs. 2nd half results give further insight into current female rugby sevens players match-running outputs (Figure 4.2). While there was no difference from 1st half to 2nd half in LMSR, this could be expected as low-moderate speed running requires less effort. However, the results also showed that there was no difference between halves for HSR, TD or sprints. This could be due to the female rugby sevens players that were used in the current study being from a top 3 world ranking team, and that women's rugby sevens is an emerging sport worldwide. Therefore, the varying level of competition standard (teams) may be much lower and require less effort. These results are different when compared to previous research on male rugby sevens that showed elite players match-running outputs decreased in the last 3 minutes of a game due to fatigue (Granateli et al, 2014; Elloumi et al, 2012). The results from the current study were interesting, as HSR requires more energy out-put and sprinting requires maximal energy out-put ultimately producing greater fatigue. Maintaining HSR and sprints, which contribute to TD, over two halves could demonstrate an elite level of fitness (Austruy, 2016). However, for the 'fairest' comparisons of fitness in elite female rugby sevens players, the data from the current study could be compared to other teams of the same elite standard.

5.4 Female Game and Tournament Match-Running Outputs

5.4.1 Football

While the data in the previous section showed deterioration in performance from the 1st to the 2nd half, there was no difference in LMSR, HSR, TD or sprints from game 1 of the tournament through to game 4 (Figure 4.4). These results are similar to previous research on elite football players, demonstrating that consistent match-running outputs are sustainable across competitions (Carling et al, 2018; Nedelec et al, 2012). Generally, it takes a 72-hour recovery period to completely restore muscle balance and the majority of subjective/objective fatigue (Carling et al, 2018). Therefore, players should be able to replicate match-running outputs after having at least a 3-day recovery period between games (Carling & Dupont, 2011). The tournament observed in the current study had a 3-day recovery period between each of the 4 games played. In elite football, large squad sizes allow for player rotation and formation changes between games during tournaments and/or competitions, enabling performance levels to be maintained (Carling et al, 2018; Nedelec et al, 2012).

5.4.2 Rugby Sevens

Across the three women's rugby sevens tournaments (Figure 4.5), there was no difference in TD and HSR. There was a difference recorded in LMSR, showing that the players covered more LMSR metres in tournament 3 than both tournament 1 and 2. The players also performed more sprints in tournament 1 compared to tournament 2, and more sprints in tournament 2 than 3. These results show a continual increase in LMSR associated with a continual decrease in number of sprints performed from tournament-to-tournament. When compared with previous research on male rugby sevens players, these results are different as match-running outputs have been shown to remain consistent across tournaments (Ross, Gill, Cronin, 2015a). This could be due to the level of opposition from tournament-to-tournament in the current study. The current study used female rugby sevens players from a top 3 world ranking team, and the level of opposition they faced may be considerably lower requiring less effort of the players. It could also be due to players suffering from fatigue from tournament to tournament. Female rugby sevens players have not been playing at an elite level for as long as the men have and therefore may not be able to replicate match-running outputs from tournament to tournament (Goodale et al, 2016).

When considering the 15 games played by the women's rugby sevens team, there was no difference recorded in LMSR, HSR and TD between games (Figures 4.6, 4.7 and 4.8). However, there was a difference recorded with players performing more sprints in game 7 than game 11. These results are different when compared with previous research on male rugby sevens players showing that match-running output deteriorates between games during a tournament (Ross, Gill, Cronin, 2015a; Granateli et al, 2014; Elloumi et al, 2012). Therefore, it would have been expected to see some difference in match-running outputs between more games. However, the results could again reflect the elite level of the players used in this study compared to their lower level of opposition (Austruy, 2016). The results showing that there was a difference in number of sprints performed between game 7 and game 11 could also possibly be due to random error.

For greater fitness comparisons of elite female rugby sevens players, data from more than one top ranking team should be collected across all tournaments of the HSBC women's world rugby sevens series and compared.

Chapter 6

APPLICATION AND CONCLUSION

6.0 Practical Applications

Based on the outcomes of this study the following practical applications were derived specifically for female rugby sevens coaches, and strength and conditioning coaches to consider when designing training sessions and individual training programs to improve overall match-running outputs and breach the current sex gaps between male and females in LMSR (64.8%), HSR (95.9%), TD (69.3%) and sprints (100%):

- Endurance training such as high intensity interval training (Nicolo et al, 2014; Robinson et al, 2014; Hottenrott, Ludyga & Schulze, 2012), could be employed to increase LMSR, HSR and TD output of players.
- Speed training such as sprinting over specific distances and repeated sprint ability training (Iaia & Bangsbo, 2010; Gabbett, 2006) could be implemented to increase speed and sprint ability, as well as HSR output of players.
- Total body strength and power based training programmes including Olympic lifts, multiple-joint exercises, exercises targeting specific muscle weaknesses and plyometric training (Simao et al, 2012; Barr et al, 2014), could be implemented to specifically increase speed, power and sprint performance of players, as well as improve muscle endurance which in effect will improve all of the four match-running output measures.
- Increasing the overall training volume/loads appropriately as well as specifically tailoring the overall training schedule of female rugby sevens players (inclusive of; rugby sevens trainings, endurance trainings, speed training and total body strength and power based trainings) (Gabbett, 2006), could also help increase each of the four match-running output measures for female rugby sevens players.

6.1 Limitations

There are a number of limitations of the current study:

- All cases referenced in the literature review as well as the data collected refer to single international rugby sevens, football and rugby union teams and therefore does not represent all international teams.

- The cases referenced in the current study were selected based on the methods (GPS) used in data collection and therefore do not represent all studies on match-running outputs of international level rugby sevens or football players. It is also important to note that multiple brands of GPS units were used from study to study, which may slightly differ in accuracy.

- The female rugby sevens data collected for the current study included three tournament legs of the HSBC Sevens World Series, however the female football data collected only contained one tournament consisting of four games.

- In the data collection of female rugby sevens and female football players match-running outputs during an international tournament, pre-tournament fitness levels were unknown. Specifically, Yo-Yo and sprint test data were unable to be attained due to access of the players. Players were based in different environments in a range of different clubs, cities and countries.

- Along with no pre-recorded fitness data for both female rugby sevens and football players, further limitations of this study also include no internal (heart rate) data, physiological attributes such as body composition measures or blood analysis (Hb levels) during tournaments.

- Again given the dispersed locations of the players outside of tournaments, no data was recorded on pre-tournament training schedules, nor was nutritional or hydration data recorded pre-tournament or during tournaments.

- The study did not have access to perceptual data including (RPE), fatigue index on match day or post-match recovery protocols during tournaments.

- The study does not include technical output measures specific to each game such as acceleration/deceleration data or time in possession/time out of possession, therefore match-running outputs could not be compared based on ball possession.

- There was a significant difference in the number of data collected on female rugby sevens players (127 player matches) compared to the number of data collected on female football players (33 player matches).

- Only 2 tournaments out of 3 for women's rugby sevens were used for 1st half vs. 2nd half comparisons as the data collected for 1 tournament was not able to be separated into discrete halves.

- In the analysis of the data collected, both female rugby sevens and female football players positional information was not specified, therefore positional differences were unable to be investigated.

- When conducting statistical analysis and comparisons on the female data collected, with research on male rugby sevens (Ross, Gill & Cronin, 2015a) and male football (Mallo et al, 2015), it is important to note that only male means and standard deviations were used from the specific studies (they conducted similar GPS methods for each sport) for comparisons, and full data sets were not used, due to lack of access and availability.

6.2 Further Research

The current study observed international female rugby sevens players match-running outputs and compared the data with current international male rugby sevens players match-running outputs, with the inclusion of male and female international football players match-running outputs for further comparisons between sports and sexes. The study also identified areas of differences in match-running outputs for female rugby sevens and female football players from 1st half to 2nd half, and between games and tournaments. The results of this study provide directions for further research:

- Incorporate heart-rate to investigate the relationship between running and non-running activities involved in rugby sevens and the differences of these activities between male and female rugby sevens players.

- Incorporate pre-tournament fitness data in order to establish base levels for individual players and teams, and to set relative speed bands to assist with greater accuracy in match-running output data comparisons.

- Further research that directly aligns male and female rugby sevens tournament match-running outputs, for example following the HSBC Sevens World Series for males and females in its entirety would eliminate a number of limitations of this study.

- Further research examining the effects on match-running outputs for both male and female rugby sevens enduring mirrored specific speed and endurance training. This type of research would give insight into physical and performance effects of identical training activities and loads between sexes.

- Further research examining the sex gap in match-running outputs found in other team-based sports of similar characteristics. Using these findings to establish an accurate sex gap between elite male and female players for team based sports. This type of research would give a benchmark or point-of-comparison for match-running outputs that are physically achievable for female players in team based sports.

- Monitor results (win/loss/draw) of each match played (rugby sevens and football) to correlate if match results positively or negatively impact match-running outputs.

6.3 Conclusions

The overall aim of this thesis was to observe international female rugby sevens players match-running outputs and compare versus expected match-running outputs. Additional sports were analysed as benchmarks and comparisons for female rugby sevens due to a lack of specific information on the female game. For comparison purposes the physical characteristics of rugby sevens, football and track and field athletics were analysed. Based on the gaps found in the literature, the objectives of this thesis were to compare international female rugby sevens players match-running outputs against international male rugby seven's players match-running outputs, using an established sex performance gap (5-12%), and an established field team-based sport (football) as a reference point. The study was successful in displaying the gap between observed match-running outputs of female rugby sevens players at an international level with expected outputs, and comparing with the established sport (football). Female rugby sevens players have significant room for improvement across all four match-running output measures (LMSR, HSR, TD and sprints) based on the findings of this thesis, and to breach the sex gap found between observed match-running outputs and expected match-running outputs. The thesis also looked to examine 1st half vs. 2nd half, game-to-game and tournament-to-tournament match-running output trends for female rugby sevens players. As there was no existing data on these aspects, the thesis succeeded in providing descriptive data for current female rugby sevens players.

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Appendices

APPENDIX 1:

IRB Women's Rugby Plan 2011-2016 (source: World Rugby, 2011a).

IRB STRATEGIC GOALS

We will measure our progress in implementing this plan in the following way:

Area	Key Performance Indicators
1 Participation and Development	1.1 400,000 registered female players by 2016 1.2 All Member Unions involved in Women's Rugby by 2013 1.3 Clear pathways and programmes in place for the Women's game in all Member Unions by 2015 1.4 Women's Rugby included in IRB Training and Education Courses by 2013
2 Global Events	2.1 Updated International Fifteens competition model with calendar in place by end of 2012 2.2 Competitive Women's Rugby World Cup 2014 in France that showcases Women's Fifteens 2.3 Global Sevens competition model confirmed by end of 2011 2.4 Women's Sevens World Series in place by 2013, featuring a minimum of 12 core teams and a minimum of four events 2.5 Inclusive Olympic Qualification model confirmed that produces the best teams 2.6 Competitive Olympic Games in 2016 that showcases Women's Sevens, featuring 12 teams 2.7 Age Grade Sevens Competitions in place at local and regional level 2.8 Deliver successful Rugby Sevens event at Youth Olympics 2014
3 Commercial & Marketing	3.1 Women's Rugby clearly identified as a viable product by 2014 3.2 Increase in broadcasting in Women's Rugby globally, including TV and new media platforms
4 Governance	4.1 Governance structures in IRB, Regional Associations and Unions effective to govern the Women's Game 4.2 Clear representation for Women's Rugby in place in IRB, Regional Associations and Member Unions
5 Acceptance & Credibility of Women's Rugby	5.1 IRB Women's Rugby Declaration Statement published 5.2 IRB Membership criteria reviewed and updated

APPENDIX 2:

IRB Rugby Sevens Plan 2011-2020 (source: World Rugby, 2011b).

1.10 WOMEN'S SEVENS

Women's Rugby Sevens is a critical component of the IRB Sevens Planning process. The key gaps identified for Women's Sevens are as follows:

- The need for a high performance programme for Women's Sevens
- The requirement to increase knowledge among Member Unions and Regions with regard to the Women's Game
- Expansion of international competition and the need for more opportunities for girls and women to play Sevens

The women's international competition model will drive the investment in high performance programmes in individual countries and will determine global performance levels. This area requires urgent investment if we are to ensure that the competiveness and performance levels of the women's Sevens competition in Rio 2016 is worthy of an Olympic sporting event. The key elements of the Women's international competition model that require prioritisation are as follows:

Stage 1: Commence IRB international invitational Sevens tournaments in 2011 and invest in Regional Tournament Structures

- There are a number of international women's Sevens invitational tournaments which take place at HSBC SWS men's events (Dubai, Las Vegas, Hong Kong)
- These events need to have a more formalised invitational process which the IRB should oversee and be organised to the same standards as the HSBC SWS

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- Three or four tournaments will be identified to form an invitational Series in 2011/12 with targeted Unions invited to participate
- Increased investment in regional tournaments in 2012 is required to ensure that as many Member Unions as possible can participate in RWC Sevens 2013 qualification

Stage 2: Implement IRB Women's Sevens World Series (IRB Women's SWS) for 2013/14 Season

- The IRB Series will consist of four or five legs with 12 teams participating in each tournament
- RWC 2013 rankings will be used to determine the core teams for the 2013/14 season
- In subsequent years there will be promotion and relegation between the IRB Women's SWS and an IRB Women's SWS qualification tournament
- Regional tournaments will continue to grow and provide qualifiers into the qualification tournament and ultimately into the Series.

Stage 3: The Olympic Games and the qualification process

- 2014/15 IRB Women's SWS will be used to qualify a number of teams directly to the Olympic Games
- Regional tournaments will act as Olympic qualifiers to qualify at least one team from each IRB Region directly to the Olympic Games
- A World Olympic Qualification tournament will be the final stage in the qualification process
- The 2015/16 IRB Women's SWS will provide the preparation platform for the teams that have qualified for the Olympic Games

Specific strategies are included in this Plan to address the gaps identified for growing the Women's Game. These include:

- Creating a pathway so that every girl has the opportunity to play this new Olympic sport
- Producing resources and programmes to facilitate the playing of the Game for young girls
- Developing a Sevens introductory programme for women and girls
- Taking an innovative approach to the development and marketing of the Women's Game

- Establishing a High Performance Working Group for Women's Rugby to identify the specific HP coaching needs for women's Sevens
- Ensuring that the appropriate expertise is in place to facilitate, organise and coordinate Women's Rugby decisions and activities
- Developing an international competition model for women's Sevens tailored to meet the specific needs of Women's Rugby
- Developing and implementing a marketing campaign to promote Sevens for girls and women to Member Unions and the Regions