Physical Characteristics and Match Performance in Rugby Sevens

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ATTESTATION OF AUTHORSHIP

"I hereby declare that this thesis submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

Alex Ross

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ABSTRACT

Rugby sevens is a contact sport contested by two teams of seven players who compete over two 7-min halves, most frequently played in a tournament style. There is currently limited research on the match demands and physical characteristics of rugby sevens players. The overall aim of this thesis was to profile the match demands and physical characteristics of players and to determine the relationship between physical characteristics and measures of match performance.

Studies one and two assessed the global match demands of international and provincial rugby sevens players and compared the match demands between forwards and backs, between tournament rounds, and between the two competition levels. Differences in running demands and match activities between international forwards and backs were trivial to moderate (ES = 0.05–0.84) while differences in running demands and match activities between Pool and Cup rounds during international tournaments were trivial (ES = 0.001–0.12), though Cup round matches showed an increase in long- duration ball-in-play sequences (proportion ratio 0.46). When comparing international and provincial players, trivial to moderate differences were found in the running demands between the completion levels, with internationals covering a greater distance at very high speed (ES = 0.30) and performing a greater frequency of sprints (ES = 0.80). There were clear differences in the frequency of all match activities between the two levels of play (ES = 0.23 – 0.64) with the exception of total tackles completed. It would seem that international rugby sevens forwards and backs experience similar match demands while international and provincial match profiles are distinguished by technical factors greater so than running demands.

Study three compared the anthropometrical and physical characteristics of international and provincial rugby sevens players as well as between forwards and backs across both playing levels. Players were assessed for height, mass, body

composition, speed, repeated sprint ability, lower body power, upper body strength, and maximal aerobic endurance. Clear differences (2.8 – 32%; small to very large effect sizes) were observed in all anthropometrical and physical measures between international and provincial players, with the largest differences observed in repeat sprint ability (5.7%; very large effect size), 40 m sprint time (4.4%; large effect size), 50 kg squat jump peak power (32%; large effect size), and multi stage fitness test performance (19%; large effect size). Fewer and smaller differences (0.7 – 14%; trivial to large effect sizes) were found when comparing forwards and backs, with subject height being the most discriminant characteristic with forwards being taller (3.5%; large effect size). Lower level rugby sevens players should therefore seek to improve their overall physiological profile, particularly their repeat sprint ability, to reach higher levels in rugby sevens. Position-specific physical preparation programs are likely not of importance in rugby sevens given the similar profiles of forwards and backs.

In study four, the relationship between defensive and attacking performance indicators and points conceded and scored, respectively, in international rugby sevens tournaments was analysed. A total of thirteen indicators were identified, with an increase of two between-team standard deviations in tackle score corresponding with a decrease of 12.4 (90% CL ± 1.8) points per match while an increase in two between-team standard deviations in line breaks resulted in an increase of 12.2 (90% CL ± 1.4) points scored per match.

The focus of study five was to examine the relationship between the performance measures assessed in study three and the performance indicators analysed in study four. Ten and 40 m sprint time had moderate to large (0.32 – 0.51) negative correlations (r) with line breaks, defenders beaten, and tackle effectiveness. Repeated sprint ability and maximal aerobic capacity were moderately related to a measure of work rate (~0.38). A decrease of two between-player standard deviations in 10 m sprint time corresponded with an increase of 74% more line breaks per match. The results of this study suggest multiple physical characteristics, in particular sprint speed, repeated sprint ability, and lower body muscular power are related to match performance in rugby sevens.

In study six, the effect of two power-training programs on physical characteristics previously shown to be related to rugby sevens performance (sprint speed and lower body muscular power) was investigated. Power training with a velocity emphasis was shown to be superior to similar training with a force emphasis in improving 10 m and 40 m sprint performance. Reductions in 10 m sprint performance across both groups were strongly related to an increase in horizontal force (r = - 0.96). It was concluded that rugby sevens players seeking to improve sprint performance should perform power training with a velocity emphasis.

Overall, the findings from this thesis have expanded on the current knowledge base specific to match demands, player characteristics, match performance and physical preparation in rugby sevens. Position-specific training programs are likely of little priority for rugby sevens players given the similar match demands and physical characteristics between forwards and backs. Further, players seeking to improve their match performance should aim to improve specific physical characteristics. Rugby sevens players who need to improve their sprint speed should employ power-training programs with a velocity as opposed to a force emphasis.

Chapter 1

PREFACE

1.1 Rationale and Significance of Research

Rugby sevens is a high intensity, intermittent field-based contact sport. The addition of rugby sevens in the 2016 Olympic games has raised the profile of the sport internationally and places an increased need to understand the various factors indicative of success within the sport. Research within the similar sport of rugby union has profiled match demands [1-4], player characteristics [5-10], and match performance analysis [11-16] with these investigations providing valuable information to coaches and support staff. Given the dissimilarities between rugby sevens and rugby union, the information from these studies may not be applicable to rugby sevens. Due to the limited research within rugby sevens [5-10, 17-24], further investigation of match demands, player characteristics and match performance is required.

Research on the physical and technical match demands of elite rugby sevens players is limited [18-20, 25]. Global positioning system [18] (GPS) and video analysis [20] have been used to define the running demands of players during tournaments. In addition to running demands, during a rugby sevens match players are required to execute a variety of activities and skills such as passing, ball carrying, and retrieving kick re-starts in addition to numerous contact situations such as tackles, rucks and scrums. As such, it would seem useful to understand the match activity profiles of rugby sevens players. Furthermore, as rugby sevens teams can be broadly split into the positions of forward and back, it would seem worthwhile to understand the differences in match demands between the positional groups in order to develop position-specific physical and technical training programs. In addition to comparing positional groups, it would also be beneficial to compare match demands between levels of play in order to distinguish the factors that distinguish elite matches from sub-elite.

There is a plethora of research within the similar rugby codes of rugby union and rugby league profiling the anthropometrical and physical characteristics of players [5, 6, 26-28]. Conversely, little is known of the physical characteristics of rugby sevens players [29, 30]. A worthwhile method to identify physical traits of importance within a sport is to compare elite and sub-elite players, as has previously been investigated in rugby union [5, 6]. Understanding the anthropometrical and physical traits related to success in rugby sevens may lead to improved talent identification and physical development programs.

An area that has received little attention in rugby sevens is technical and tactical match performance. Whilst studies of factors related to match performance are prevalent in rugby union [12, 14-16, 31-33], little is known of the factors related to rugby sevens performance [19]. Given the vast differences in rules and competition format between rugby sevens and rugby union, it would seem likely that the tactical and technical strategies related to success in rugby union may have limited applicability to rugby sevens. Understanding the individual and team technical and tactical factors related to performance in rugby sevens would benefit coaches in developing individual and team match performance profiles and guide subsequent training programs.

As athletes progress over time, the specificity of their training becomes all the more important in order to continue to improve. As such, their physical preparation should reflect an understanding of the importance of various physical characteristics to on-field performance. Comparing the relationship between physical characteristics and match activities associated with success provides valuable information to guide specific training programs. An investigation in rugby union [34] provided useful information on the strength of relationships between physical characteristics and match performance, however no such investigation exists specific to rugby sevens. Lastly, once physical traits indicative of success in rugby sevens have been identified, investigating the effect of different training programmes and training objectives on physical performance in rugby sevens players would provide further information for coaches when developing specific training programs for their athletes.

With the aforementioned gaps in rugby sevens research, this PhD thesis was developed to contribute to the scant body of knowledge in match demands, physical characteristics, match performance indicators and physical preparation in rugby sevens players and teams. The overall aim of this thesis was to assess the relationship between physical characteristics and match performance in rugby sevens.

1.2 Purpose of Research

In order to assess the relationship between physical characteristics and match performance, six sequentially ordered studies were undertaken. The specific objectives of these studies were to:

1. Investigate the match demands of international rugby sevens forwards and backs.
2. Compare the technical and running demands of international and provincial level matches.
3. Compare the anthropometric and physical characteristics of international and provincial rugby sevens players and between forwards and backs.
4. Investigate individual attacking and defensive match performance indicators.
5. Investigate the relationship between physical characteristics and match performance indicators.

6. Investigate the effect of different training programs on the sprint speed, mechanical sprint characteristics, and lower body muscular power of rugby sevens players.

1.3 Significance of Thesis

Prior to designing specific training programs and establishing normative profiles for analysis, the match demands must first be known. However, the physical and technical demands of rugby sevens remain unclear. Understanding the physical and technical demands of rugby sevens and how these demands differ across tournament rounds, between positional groups, and between competition levels would be useful for training program design and to inform performance analysis.

In addition to understanding the match demands of rugby sevens, it is also important to have knowledge of the physical characteristics of rugby sevens players. Comparing the anthropometrical and physical characteristics of rugby sevens forwards and backs can inform position-specific training programs and aid in talent identification. Further, comparing elite and sub-elite rugby sevens players may shed light on the physical traits that distinguish players of different playing ability that would be of likely importance.

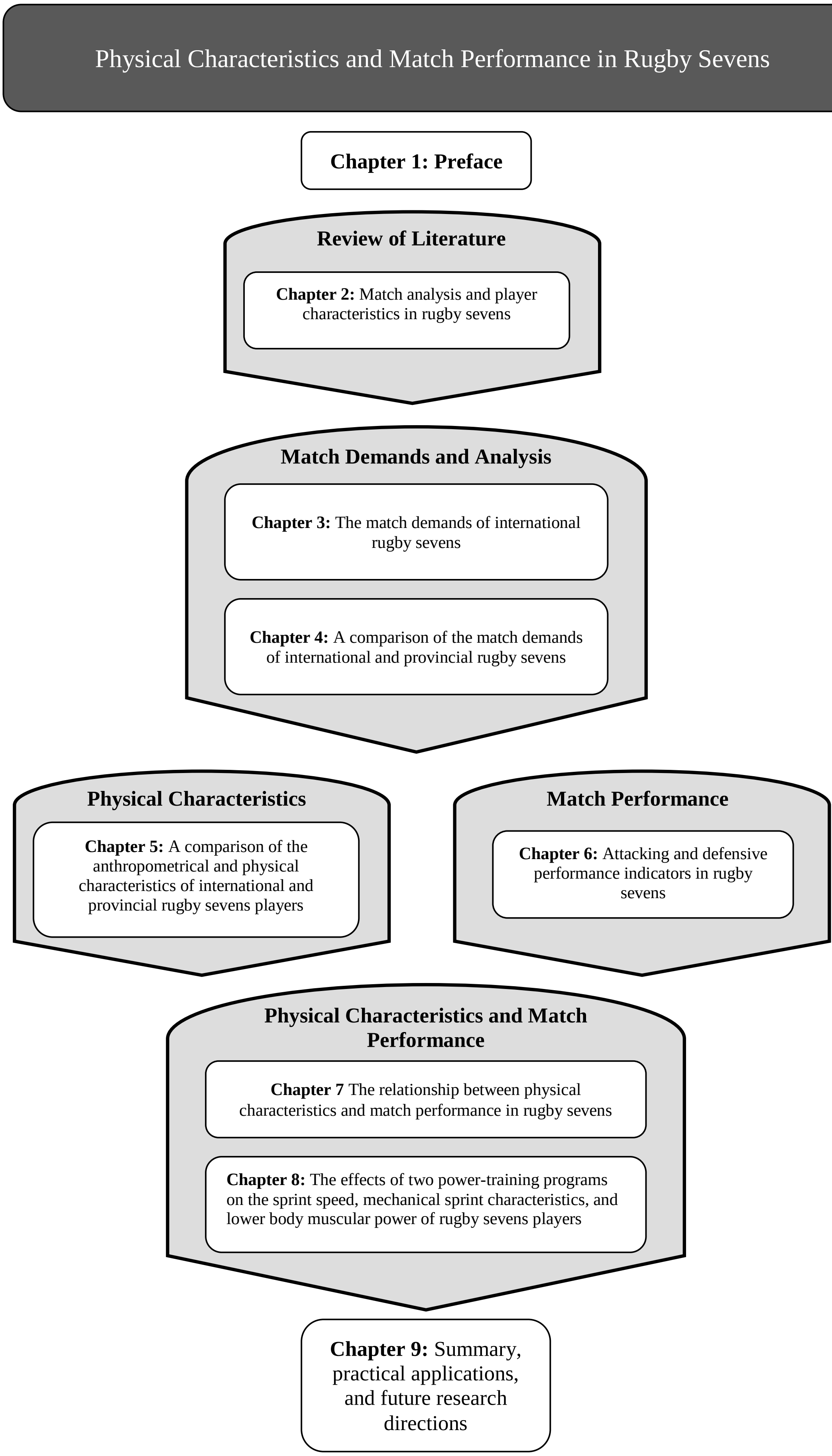
While knowledge of the team factors that influence performance and match outcomes in rugby sevens are useful, it would also be beneficial to know the individual match activities indicative of performance in rugby sevens. Analysis of performance at the individual level would aid in creating more effective performance analysis strategies. An increased level of individual player performance profiling would be gained by investigating the relationship between physical characteristics and match performance. Knowing how different physical traits relate to on-field performance would provide for an even higher level of specificity when designing training programs. Finally, once the physical traits related to match performance have been defined, it would be advantageous to understand the effect of different training methods on improving a physical trait related to performance.

The match analysis, physical profiling and investigation of the relationship between physical characteristics and match performance will add to the currently limited knowledge base within elite rugby sevens. As such, the outcomes of this thesis would be of greatest benefit to international rugby sevens teams, though club and semi-elite teams would also likely benefit in whole or from part of the information provided.

1.4 Structure of the Thesis

To answer the overarching question of the relationship between physical characteristics and match performance in rugby sevens, this thesis is comprised of five main, sequential sections (See Figure 1.1). The first section (Chapter 2) is a literature review of the research specific to match analysis and players characteristics in rugby sevens. The second section profiles and compares the match demands of international and provincial level rugby sevens (Chapters 3 and 4). The third section profiles and compares the anthropometrical and physical characteristics of international and provincial rugby sevens players (Chapter 5). Section four focuses on individual and team technical and tactical factors related to success in international rugby sevens matches (Chapter 6). The focus of the final section was to investigate the relationship between physical characteristics and match factors indicative of success in rugby sevens (Chapter 7) and the effect of short-term, high-velocity and high-force training on the sprint speed, mechanical sprint characteristics and lower body muscular power of rugby sevens players (Chapter 8).

Figure 1.1 Thesis schematic



Chapter 2

MATCH ANALYSIS AND PLAYER CHARACTERISTICS IN RUGBY SEVENS

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2.0 Lead Summary

Rugby sevens is a contact sport contested by two teams of 7 players who compete over two 7-minute halves, most frequently played in a tournament style. The IRB Sevens World Series is thought of as the preeminent rugby sevens competition in the world and has grown in competitiveness from its inception in 2000. The decision to include rugby sevens in the 2016 Olympics is likely to increase the global profile and participation in the game. Many rugby sevens players concurrently compete in 15-a-side rugby union as backs and loose forwards; however a continued increase in the popularity of rugby sevens will likely see the emergence of the specialist rugby sevens player.

Often thought of as the abbreviated version of rugby union, rugby sevens is played under nearly identical laws and on the same field dimensions as the 15-man code. However, research has shown the movement demands of rugby sevens and 15-a-side rugby union are dissimilar, with rugby sevens players spending a larger proportion of the game running at high intensity (≥ 5 m.s^{-1}). Given the dissemblance in match demands in conjunction with differences in the competition structure between the codes, it appears the considerable depth of literature specific to performance in 15-a-side rugby union may be of little value for the preparation of rugby sevens players.

Investigations of the physical characteristics of rugby sevens players show backs are lighter and shorter than forwards, while players across all positions possess a lean body composition. International rugby sevens players have similar speed characteristics to 15-a-side backs across distances of 10 – 30 m however rugby sevens players appear to have superior intermittent aerobic endurance. Despite being of likely importance, little is known of the strength and power characteristics of rugby sevens players. Research of the speed and aerobic endurance characteristics of rugby sevens players has not distinguished between backs and forwards and as such, it is unclear whether differences exist between the position groups.

The purpose of this review is to examine the current literature specific to rugby sevens match analysis and player characteristics with a focus on identifying future areas for investigation.

2.1 Introduction

Seven-a-side rugby union (i.e. rugby sevens) is an intermittent, field based team sport characterized by frequent bouts of high intensity activity and collisions. Rugby sevens is played under essentially the same laws as 15-a-side rugby union including the same playing field dimensions. However, rugby sevens is played with fewer athletes per team (seven as opposed to fifteen) and for a shorter duration i.e. 7-minute halves with a 1-2 minute halftime as compared to 40-minute halves and a 10-15 minute halftime. In addition, unlike 15-a-side which is played typically every 5-7 days, rugby sevens is generally played in a tournament format with teams contesting 5-6 matches over the course of 2-3 days.

The IRB Sevens World Series, consisting of 8-10 tournaments per season with 16-24 international teams competing at each tournament, was formed in 1999 and is widely regarded as the highest standard of rugby sevens competition in the world. Arguably providing the largest improvement in the popularity and profile of rugby sevens was the decision in 2009 to include rugby sevens in the Olympics beginning in 2016, with countries receiving increased financial and administrative support from their respective Olympic committees. However, despite a robust annual international competition and the significance of Olympic inclusion, little is understood of rugby sevens players and competition.

Investigations specific to performance in rugby sevens are limited, with studies of match analysis [18-20, 25], training load monitoring [35], and physical profiling [29] comprising the totality of research. Additional studies provided information on the injury epidemiology and anthropometry of rugby sevens players [22, 30, 36]. Comparatively, performance in 15-a-side rugby union has received a strong research focus with investigations into match play [1, 2, 4, 37, 38]physical profiling [5, 6, 9, 10, 34] and differences in players across levels of competition [5, 6, 8]. The results of investigations in 15-a-side rugby union has yielded valuable information for coaches and conditioners [39, 40] for that format of the game.

Although rugby sevens and 15-a-side rugby union are played under the same rules and with the same field dimensions, the differences in the match duration and number of players contesting suggests that 15-a-side rugby union training methodologies may have little application to rugby sevens. Whilst there are skills that are applicable to both forms of rugby (e.g. passing, tackling, ball carrying) it is likely that there are also skills and factors related to success specific to rugby sevens. Furthermore, although many rugby sevens players also concurrently compete in 15-a-side rugby union, a continued increase in competition level and support from national rugby unions and Olympic committees will likely result in the development of the specialist rugby sevens player, with physical characteristics and skills unique to the sport. With this in mind, the objective of this review is to summarize the current literature on the match demands and physical and physiological characteristics of rugby sevens players and identify directions for future research.

2.2 Match Demands

2.2.1 Time-motion Analysis

Time motion analysis is a commonly used method within intermittent team sports to track and analyse player movement [1-3, 17, 18, 20, 25, 37]. An account of movement patterns such as the total distance ran, average speeds, and number and distance of sprints ran are all important in assessing the specific match demands of players, and is also useful when assessing and tracking individual players [3, 37, 41]. Time motion analysis in rugby sevens and 15-a-side rugby union has been performed via video analysis [2, 3, 20], computer based tracking [1, 17, 42] and more recently through global positioning system (GPS) technology [4, 18, 25, 43, 44].

Time-motion analysis of rugby sevens has used video analysis [20] and GPS [18, 25], with researchers reporting that rugby sevens players travel a total distance of between ~113 – 120 meters per minute ($m\text{-}min^{-1}$). International players cover ~19% of the total distance during a match at ≥ 5 $m.s^{-1}$ and ~11% at ≥ 6 $m.s^{-1}$ International players also perform 39% more high velocity (≥ 4 $m.s^{-1}$) accelerations and cover 27% more distance sprinting (≥ 6 $m.s^{-1}$) when competing in international tournaments compared to when competing in domestic tournaments, suggesting physical demands increase as the competition level improves [18].

While investigations within 15-a-side rugby union have revealed large differences in the movement patterns of backs and forwards [1, 4, 12, 45], it remains unclear whether differences exist in the movement patterns of rugby sevens backs and forwards, as most investigations of rugby sevens players have not distinguished players by position. While it seems likely that rugby sevens players would be more uniform in terms of their movement patterns across positions when compared to 15-a-side rugby union, there is little evidence to support this contention. To date, only one study has investigated the movement patterns of rugby sevens backs and forwards separately [20]. Using video based time-motion analysis with subjective movement speed categories, Rienzi et al. [20] reported rugby sevens forwards spent 19% more time jogging while backs spent 8% more time running. However only one tournament was used for analysis and the intra-observer reliability for the method of analysis was not reported. The subjective assessment of movement speeds used in the study make comparisons to studies using GPS difficult, furthermore the tournament analysed was played in 1995.

An investigation comparing the movement patterns of contemporary rugby sevens forwards and backs, through the use of GPS, is warranted.

Rugby sevens is predominantly played in a tournament style where teams will contest between five and six matches over the course of one to three days, requiring players to compete multiple times throughout each day. It would seem likely that the cumulative fatigue from playing multiple matches throughout a tournament would affect player movement patterns and match activities as a tournament progresses. However, Higham et al. [18] reported small (4.6% - 8.4%) differences in low to moderate velocity movements (0 $m.s^{-1}$ - 5 $m.s^{-1}$) between the first and last matches of rugby sevens tournaments while differences in high speed running (5 - 6 $m.s^{-1}$) and sprinting ($\geq$ 6 $m.s^{-1}$) were unclear. The authors suggest that the between-match recovery strategies employed by the participants in the study may have helped mitigate fatigue.

Though it appears fatigue does not affect movement patterns between games, researchers have suggested that fatigue may impact movement patterns within games. Analysis of the movement patterns comparing halves of rugby sevens matches by players who contest the whole match indicates that a decrease in work-rate exists from the first to second half e.g. decreases in total distance covered (~6%), frequency of accelerations (13%), and time spent in high intensity running (10%) [18]. As well, substitute players perform a significantly greater amount of high intensity running (123%) in the second half when compared to players who contest the entire match. Furthermore, analysis of the heart rate responses of rugby sevens players between halves suggest fatigue may affect relative intensity with time spent at $\geq$ 90% maximal heart rate higher (~9%) in the second half, despite no increases in running measures from the first to second half [18, 25].

While sprinting appears to be an important part of rugby sevens, little is known of the characteristics of sprints, such as the frequency, distances covered, and rest between efforts during competition. Suarez-Arrones et al. [25] reported rugby sevens players perform ~7 sprints (≥ 5.6 $m.s^{-1}$) per match covering an average distance ~20m, however only a small sample (n = 7) of domestic level players were analysed. Higham et al. [18] provided information on the total distance covered at sprint speed (≥ 6 $m.s^{-1}$) by international players during domestic and international competitions, however the authors did not report the distances or frequency of sprints. Further analysis of the sprint characteristics of international rugby sevens players during competition using a large sample would aid in informing speed training and assessment, as it would seem of importance to assess and train players across distances they would commonly cover during competition.

2.2.2 Notational Analysis

Notational analysis of match play provides an objective analysis of both individual and team performance through analysis of the frequency, duration and characteristics of key tasks throughout a match. The information notational analysis provides is critical to the development of success factors and of individual player assessments that can be used to track the performance of players and teams both within a season as well as across many seasons [12, 17]. Notational analysis is also of use when supplemented to movement pattern data to provide a more in depth analysis of match demands [1, 11-13, 15, 17, 33, 46].

Notational analysis has received a great deal of attention in 15-a-side rugby union [1, 11, 13, 15, 17, 33, 38, 46] as well as in other intermittent contact sports such as Australian football [47-50] and rugby league [51]. Notational analysis has been used in 15-a-side rugby union to determine positional differences in match demands [1, 2, 12], analyse performance [13, 14] and as a means to determine team and individual skills related to success [11-14]. James et al.[12] used notational analysis to analyse elite 15-a-side rugby union players and determine position specific success factors.

Understanding the team and individual match skills related to success allows coaches to objectively measure performance and aids in informing the training process. An investigation of the match skills related to success in rugby sevens has not been performed, however is required if the understanding of performance in rugby sevens is to be improved.

There is a paucity of research relating to notational analysis of rugby sevens competition as to date there have been only two investigations [19, 24]. Hughes and Jones [24] compared the playing patterns of successful (winning percentage ≥ 70%) and unsuccessful (winning percentage < 70%) teams from sixteen games from the 2001 IRB Sevens World Series. The authors reported successful teams on average formed 33% fewer rucks, missed 50% fewer tackles and had 21% more clean line breaks than unsuccessful teams. Van Rooyen et al. [19] examined the duration and frequency of different phases of the rugby sevens match as well as the differences in these statistics between teams that made the semi finals and those that did not at the 2005 Rugby Sevens World Cup. The authors reported the time of ball in play per match was 7:18 (min), with each team possessing the ball for an average of 3:55 (min), while there were no differences in possession time per match between semi finalists and quarter finalists. While the results of these studies may have implications for tactical strategy they do not provide information on individual match demands, which would aid in informing match specific training.

2.2.3 Differences in Match Demands between Rugby Sevens and Fifteen-a-side Rugby Union

Rugby sevens players often also compete in 15-a-side rugby union, most commonly participating as a back or loose forward. Investigations of the movement patterns of rugby sevens [18, 20, 25] and 15-a-side rugby union [1, 2, 4] show clear differences exist between rugby sevens players and 15-a-side backs and loose forwards, as it appears rugby sevens is played at a higher relative intensity as evidenced by the increase in proportion of distance of high intensity running (see Table 2.1). International rugby sevens players have been shown to cover 120 m-min^{-1}, a 69% greater relative distance compared to 15-a-side backs (71 m-min^{-1}) and loose forwards (65 m-min^{-1}) [4, 18]. The total distance covered in a single rugby sevens match is considerably less than in 15-a-side rugby, not surprising given the large difference in match time (14 and 80 mins, rugby sevens and 15-a-side, respectively). However, rugby sevens players most often participate in three matches in a day and five to six games over the course of two days while 15-a-side rugby union players will rarely play two matches with fewer than four days rest in between. The differences in competition structure between the two formats has implications for training, as rugby sevens players must be prepared to compete multiple times within a day and on consecutive days.

Table 2.1 Summary of movement patterns of rugby sevens players and 15-a-side rugby union backs and loose forwards during competition using GPS

Study (y)	Subjects (n)	Position	TD (m-min)	% TD High intensity running
Cahill et al. [4] 2012	Elite 15's (216)	Back (151)	71	~13[a]
		Loose forward (65)	65	~16[a]
Coughlan et al. [44] 2011	Elite 15's (1)	Back	73	~9[b]
Cunniffe et al. [43] 2009	Elite 15's (1)	Back	72	~11[b]
Higham et al. [18] 2011	International 7's (18)	Not specified	120	~19[b]
Suarez- Arrones et al. [25] 2012	Domestic 7's (7)	Not specified	113	~14[b]
Suarez- Arrones et al. [45] 2012	Domestic 15's (7)	Back	81	~13[b]

TD = Total distance, m.min^{-1} = meters per minute, 7's = rugby sevens, 15's = 15-a-side rugby union;
a ≥ 51% of maximal velocity reached during a match
b ≥ 5 m s^{-1}

In addition to investigating the differences in movement patterns of rugby sevens and 15-a-side rugby union players, the non-running physical demands such as rucking, tackling, mauling and scrummaging must also be accounted for as these movements also contribute to the physical load of players during competition. With a relatively greater area for players to cover, it would seem tackles and rucks would occur less frequently in rugby sevens than in 15-a-side rugby union. However, though the individual non-running demands in 15-a-side rugby union players have been reported [1, 2, 52], no investigations exist in rugby sevens.

2.2.4 The Relationship between Physical Measures and Match Skills

Success in rugby sevens, like many intermittent team sports, is multifactorial with technical, tactical and physical factors all contributing. Coaches often seek to improve their athletes performance through developing the physical characteristics thought to be associated with specific skills. Understanding the degree to which physical characteristics are related to match skills enhances the training process by allowing coaches to develop targeted training programs to improve specific match skills [34]. Studies within 15-a-side rugby union [34], Australian football [49, 53], and rugby league [54] have investigated the relationship between physical characteristics and specific match skills.

In a recent study in 15-a-side rugby union [34]researchers identified the relationship between physical measures (i.e. body composition, speed, strength, endurance) with specific match tasks (i.e. line breaks, tackles made, work rate). Smart et al. [34]reported mostly small and moderate correlations for relationships between physical traits and match related skills in professional and international players. The lack of large correlations however does not necessarily indicate physical measures are not related to match skills, as it is possible that physical measures other than those included by Smart et al. [34] may have stronger correlations with match skills.

While it is clear that factors independent of physical measures such as tactical awareness, technical skill, and playing experience influence performance during competition in field sports, an understanding of how specific match skills are related to selected physical measures may have important training implications. Whilst the non-running demands of rugby sevens remain unclear, the high intensity running and sprint demands would suggest physical measures would likely influence the ability to execute match skills. Therefore, an investigation of the relationship between physical measures and match skills in rugby sevens is warranted.

2.3 Anthropometric and Physiological Characteristics

Rugby sevens is a high intensity sport that requires players to possess a broad range of physical characteristics. Investigations of the physical demands of rugby sevens suggest players must possess speed, strength, power and aerobic endurance. However, studies reporting the physical characteristics of rugby sevens are limited [18, 20, 25, 29, 30, 35, 36]. The results of studies in similar intermittent sports such as 15-a-side rugby union, rugby league, and Australian football reporting the physical characteristics of elite players [5, 6, 9, 10, 55] as well as differences in physical characteristics between players of different competition level [6, 8, 26, 54, 55] has yielded valuable information for those sports. An understanding of the physical characteristics that define and distinguish rugby sevens players of different rank would likely be of value to coaches and trainers.

2.3.1 Anthropometry

Anthropometrical measures are used in many sports when describing the characteristics of athletes and are often used to distinguish between age, rank (e.g. starters vs. non-starters) and positional group [7]. Anthropometric measurement of rugby sevens players has received attention (see Table 2.2) with studies in player profiling, time motion analysis, load monitoring and injury epidemiology reporting anthropometric measures of rugby sevens players.

While most studies of anthropometry amongst 15-a-side rugby union players distinguish between backs and forwards due to the large variance in physical characteristics between positional groups [3, 9, 10, 17, 45], most studies of rugby sevens players [18, 22, 25, 29, 35], but not all [20, 30], have pooled the backs and forwards data. Recently researchers in a study of rugby sevens players suggested teams were more homogenous across positions than in 15-a-side rugby union, as evidenced by the small variance in anthropometrical measures with the coefficient of variation (CV) ranging from 3.3 - 8.4% [29]. However, it appears that the anthropometrical homogeneity within the team investigated by Higham et al. [29] may not apply to rugby sevens players in general. Indeed, an investigation of a large sample (n= 264) of international players reported forwards as ~12 kg heavier ($p < .001$) and ~7 cm taller ($p < .001$) than backs [30]. Though differences between positional groups appear less pronounced than in 15-a-side rugby union, it would seem necessary to distinguish between backs and forwards when reporting the anthropometrical characteristics of rugby sevens players.

When compared to 15-a-side rugby union players it would appear that rugby sevens players are significantly lighter when not grouped by position. However, rugby sevens players are similar in mass (~90 kg) and stature (~1.83 m) when compared to outside backs in 15-a-side rugby union (~89 kg, 1.80 m) [5, 30]. When position is reported, rugby sevens forwards are similar in body mass to loose forwards in 15-a-side rugby union (~98 kg and 102 kg, respectively) while rugby sevens backs are similar in body mass to 15-a-side outside backs (~87 kg and 89 kg, respectively) [5, 30].

A lean body composition would be advantageous given the high intensity running demands of rugby sevens [18, 25]. Indeed, researchers reporting measures of body composition have shown rugby sevens players are lean, as indicated by estimated body fat percentage (~11% -12%) and the sum of seven skinfolds (52.2mm – 61.6mm) [20, 25, 29]. It has been shown that backs are leaner than forwards in 15-a-side rugby union [5, 7], however it is unclear whether differences exist in body composition between contemporary rugby sevens players as the only study to report the body composition of backs and forwards separately investigated players in 1996 [20].

The trend of players in 15-a-side rugby union growing larger in recent years [17] appears to also exist in rugby sevens with international backs and forwards an average of ~7 kg and ~4 kg heavier, respectively, than backs and forwards in 1996 [20, 30]. Investigators in 15-a-side rugby union have also reported differences in anthropometry between players of different competition level [5, 6] however there have been no investigations comparing rugby sevens players of different rank. Investigations of the differences in anthropometric characteristics between rugby sevens players of different playing status (international, provincial) could have implications for player development and talent identification.

Table 2.2 Anthropometric characteristics of rugby sevens players

Study (y)	Subjects (n)	Position	Height (cm)	Mass (Kg)	Body composition
Elloumi et al. [35] (2012)	International (16)	NS	183 ± 0.10	87.3 ± 7.4	11.3%[b]
Fuller et al. [30] (2010)	International (264)	Back (162)	180 ± 6.40	86.0 ± 7.80	NR
		Forward (88)	187 ± 5.80	97.7 ± 7.20	NR
		Not specified (14)	183 ± 7.10	90.1 ± 9.50	NR
Higham et al. [18] (2012)	International (19)	NS	182 ± 0.50	89.7 ± 7.30	NR
Higham et al. [29] (2013)	International (18)	NS	183 ± 0.06	89.7 ± 7.60	52.2mm[a]
Rienzi et al. [20] (1999)	International (30)	Back (13)	176 ± 5.10	78.6 ± 7.10	11.4%[b]
		Forward (17)	185 ± 4.60	93.5 ± 7.80	12.1%[b]
Suarez Arrones et al. [25] (2012)	Domestic (7)	NS	180 ± 7.80	87.9 ± 11.0	61.6mm[a]
Takahashi et al. [22] (2006)	International (7)	NS	179 ± 7.90	86.4 ± 8.40	NR

Anthropometric values are expressed as mean ± SD

a Estimated body fat percentage according to sum of four skinfolds (supra-illiac, biceps, triceps,and sub-scapular)

b Sum of seven skinfolds (biceps, triceps, subscapular, suprailiac, abdomen, front thigh and medial calf)

NR Not reported

2.3.2 Speed

Speed and acceleration are important components in field sports where the ability to cover ground quickly from varying starting speeds is critical to success [39]. With only 14 players on the same size field as in 15-a-side rugby union it would appear the ability to rapidly cover ground would be advantageous for rugby sevens players. However, though it appears sprinting occurs frequently during competition and speed is an advantageous physical trait, little is known of the speed characteristics of elite rugby sevens players.

Two studies have reported the speed characteristics of rugby sevens players (see Table 2.3). Higham et al. [29] reported elite international rugby sevens players have 10 m, 30 m, and 40 m sprint times of 1.74 s, 4.02 s, and 5.11 s and maximal velocity (velocity over 30 m – 40 m during 40 m sprint) of 9.2 $m.s^{-1}$. When compared to elite

15-a-side rugby union backs, international rugby sevens players appear to have slower speed across 10 m (1.74 s and 1.68 s - 1.69 s, rugby sevens and outside backs, respectively) and similar speed over 30 m (4.02 s and 4.04 s – 4.11 s, rugby sevens and outside backs, respectively) [29, 34]. Inconsistencies between studies in sprint testing protocols (e.g. running surface, starting stance) notwithstanding, a deficiency of research makes conclusive statements on normative speed values for rugby sevens players, as well as how they compare to 15-a-side rugby union players, tenuous. Further examination of the speed characteristics of rugby sevens players from a variety of competition levels may be of interest in talent identification and player development.

Table 2.3 Summary of speed characteristics of rugby sevens players and 15-a-side rugby union backs and loose forwards

Study (y)	Subjects (n)	Position	Assessment				
			10 m (s)	20 m (s)	30 m (s)	40 m (s)	V_{max} ($m \cdot s^{-1}$)
Crewther et al. [9] (2009)	Elite 15's (11)	Back	1.73 ± 0.06	2.96 ± 0.09	NR	NR	NR
Duthie et al. [3] (2006)	Elite 15's (7)	Back	NR	NR	NR	NR	9.20 ± 0.30
Elloumi et al. [35] (2012)	International 7's (16)	Not specified	1.80 ± 0.07	3.09 ± 0.07	4.28 ± 0.12	NR	NR
Higham et al. [29] (2013)	International 7's (18)	Not specified	1.74 ± 0.06	2.92 ± 0.08	4.02 ± 0.11	5.11 ± 0.15	9.20 ± 0.40
Smart et al. [5] (2011)	Amateur, professional, Semi-professional 15's (379)	Back (172)	1.68 ± 0.44	2.89 ± 0.33	4.11 ± 0.39	NR	NR
		Loose forward (207)	1.76 ± 0.07	3.06 ± 0.44	NR	NR	NR
Smart et al. [34] (2012)	Elite 15's (231)	Back	1.69 ± 0.07	NR	4.04 ± 0.14	NR	NR

Speed values expressed as mean ± SD
NR = Not reported, V_{max} = Maximal velocity reached in 40-60 m sprint, 15's = 15-a-side rugby union, 7's = Rugby sevens

In addition to assessing speed over standardized distances (e.g. 10 – 40 m), understanding the acceleration and maximal speed characteristics of rugby sevens players would also seem of importance as it has been suggested these measures are independent of one another [56, 57]. Researchers studying elite Australian football players examined the relationship between different sprint distances and reported a strong correlation between 10 m time and 20 m (r = 0.94), 30 m (r = 0.89) and 40 m (r= 0.81) suggesting these times are influenced heavily by acceleration [56]. However, a weaker relationship (r = 0.50) was identified between 10 m time and time over 20-40 m, suggesting 20 m – 40 m time is more dependent on maximal speed rather than acceleration. A similar distinction between measures of acceleration and maximal speed was also reported in an investigation of elite American football players where small and trivial relationships were observed between speed over 0 - 9.1 m and 18.3 m - 36.6 m speed during a 36.6 m sprint across all positions [57]. Both acceleration and maximal speed are of likely importance for the rugby sevens player and may be of importance in developing specific training programs.

2.3.3 Muscular Strength and Power

High levels of muscular strength and power are thought to be critical to success in collision-based sports [5, 6, 8-10, 23, 34]. Rugby sevens players engage in similar contact situations to 15-a-side rugby union and rugby league such as tackling, rucking, carrying the ball into contact, mauling and scrummaging, which all require strength and power. While numerous studies have reported the strength and power of 15-a-side rugby union players [5, 6, 8, 9, 23, 34, 58], there is a dearth of research reporting such data for rugby sevens players.

Investigations of the strength and power of 15-a-side rugby union players have reported forwards are stronger and more powerful than backs [5, 9] while older players are stronger and more powerful than younger players [5, 6]. Muscular strength in 15-a-side rugby union players is commonly assessed through one to three-repetition maximum in the bench press, squat, chin up and power clean. The majority of studies reporting the strength characteristics of 15-a-side rugby union players have not distinguished between positional groups when reporting strength, which is problematic as it would seem there is little value in comparing for example a 15-a-side rugby union prop to a rugby sevens wing. Smart et al. [34] investigated strength characteristics of 15-a-side rugby union players by positional group reporting the average box squat, bench press, chin-up and power clean 1RM were 157 kg, 109 kg, 123 kg, and 90 kg respectively, for outside backs, while the average box squat, bench press, chin-up and power clean 1RM were 169 kg, 119 kg, 132 kg, and 98 kg respectively for loose forwards. While muscular strength is likely beneficial due to the tackling and ruck demands, no studies have reported the strength characteristics of rugby sevens players.

The ability to produce maximal muscular power is critical to success in many sports, particularly sports involving frequent collisions [26, 46]. Power expression is interrelated to many skills such as sprinting, jumping [59, 60] and tackling ability [61]. Power has also been reported to be a better predictor than strength of playing level amongst rugby league and 15-a-side rugby union players [6, 26]. Muscular power is generally assessed in the lower body using the loaded jump squat and through loaded bench throws in the upper body [6, 26]. Lower body power is more commonly reported than upper body power in investigations involving 15-a-side rugby union and rugby league players as the various sprinting, jumping, and tackling actions performed during matches are more reliant on lower body power [26, 61]. Despite the likely requirement of upper and lower body power, only one study has reported power values for rugby sevens players [29]. Higham et al. [29]used the counter movement vertical jump and reported similar results (66.3 cm) to elite rugby league players (63.9 cm) [61].

Clearly, further research on the muscular strength and power characteristics in rugby sevens players is required. Though the majority of researchers describing the muscular strength and power characteristics of 15-a-side rugby union players reported measures as absolute values, it would seem of value to normalize strength and power to individual body mass, through allometric scaling [10], particularly in rugby sevens where players are likely to possess a lean body composition.

2.3.4 Maximal Aerobic Power

The aerobic energy system aids in recovery between sprints, replenishing phosphocreatine between efforts, critical to success in intermittent sprint sports [62, 63]. The aerobic energy system is also suggested to improve recovery after high intensity exercise, which has implications for rugby sevens tournaments where multiple matches are played in a day and over consecutive days with one to three hours between matches [63]. Furthermore, international rugby sevens players typically cover ~1650 meters per fourteen minute match, of which ~19% is covered at speeds ≥ 5 m.s^{-1}, in conjunction with frequent bouts of sprinting, accelerating, and decelerating [18, 25], suggesting a need for a well developed aerobic energy system.

Two studies have reported the aerobic ability of rugby sevens players (see Table 2.4) [29, 35]. Both studies used variations of the Yo-Yo Intermittent test to assess aerobic fitness, which consists of a series of progressively faster 20-m shuttles to exhaustion with 5 seconds rest between shuttles for the endurance version and 10 seconds active rest for the recovery version. Both versions also have two levels with level two consisting of faster shuttle speeds than level one [64, 65]. The Yo-Yo Intermittent test variations are thought to be a more valid measure of intermittent field sport endurance than traditional laboratory derived maximal oxygen uptake (VO_2max)

[66]. Indeed, researchers in a recent study of soccer players reported performance in the Yo-Yo Intermittent Recovery test was able to distinguish between elite and sub-elite players when VO_2max recorded from a maximal treadmill test did not [66].

Higham et al.[29] reported international rugby sevens players achieved an average total distance of 2256-m in the Yo-Yo Intermittent Recovery Test level 1 (YYIRT1). This result is greater than elite rugby league players (1656-m) of similar body mass [67] and a combined group of elite 15-a-side rugby union and rugby league backs (2040-m) [68]. Investigations of intermittent field sports such as Australian football [69], rugby league [67], and soccer [66] have reported elite players achieve greater distances in intermittent shuttle field tests than sub-elite players. However, despite the likely influence of aerobic fitness on performance in rugby sevens, there have been no investigations of differences in aerobic fitness between rugby sevens players of different competition level.

Table 2.4 Summary of studies reporting aerobic performance of rugby sevens players and 15-a-side rugby union and rugby league backs

Study (y)	Subjects (n)	Position	Assessment	Result (m)
Austin et al. [68] (2012)	Elite 15's and rugby league (12)	Back	YYIR1	TD = 2040 ± 440
Elloumi et al. [35] (2012)	International 7's (16)	Not specified	YYIE2	TD = 1925 ± 332
Higham et al. [29] (2013)	International 7's (18)	Not specified	YYIR1	TD = 2256 ± 268
Nirmalendran and Ingle [70] (2010)	Elite 15's (15)	Back	MSFT	TD = 2311 ± 212
Quarrie et al. [71] (1995)	Elite 15's (44)	Back	MSFT	TD = 2540
Tong and Mayes [72] (1996)	Elite 15's (21)	Back	MSFT	TD = 2520

Aerobic measures expressed as mean ± SD
MSFT = 20 m Multi Stage Fitness Test, YYIE2 = Yo-Yo Intermittent Endurance test level 2, YYIR1 = Yo-Yo Intermittent recovery Test Level 1, TD = Total distance

2.3.5 Repeated Sprint Ability

The ability to maintain speed over a series of sprints with minimal rest, termed repeated sprint ability (RSA) is thought to be an important part of success in high intensity intermittent sports [73]. Repeated sprint ability is measured using a number of assessments, however all feature a series of short sprints (≤ 6 seconds) with short recoveries (≤ 30 seconds). Scores are generally reported as mean time of sprints (average time across all sprints), total time of sprints (sum of all sprints), fatigue index (difference between best sprint and worst sprint expressed as a percent) and sprint decrement (sum of all sprints divided by the best sprint x number of sprints, expressed as a percent) [74]. Mean time has been shown to be highly correlated ($r = 0.97$) with the fastest sprint [75] while the index of fatigue and sprint decrement are correlated ($r = -0.54$) with lactate threshold [76].

Only one study to date has investigated the RSA of rugby sevens players [29]. Higham et al. [29] reported a total time of 24.76 s for international players when completing 6 x 30-m sprints starting each sprint every 30 seconds. While this study provided a starting point of the analysis of RSA in rugby sevens players, further investigation should seek to examine the utility of RSA as a discriminatory measure between players of different competition levels.

2.4 Conclusion

It is readily apparent from this review that further investigation of performance in rugby sevens is warranted. Whilst played under essentially the same laws, it is apparent that the movement patterns and subsequent physical demands of rugby sevens and 15-a-side rugby union players vary greatly between the codes, suggesting the bevy of studies related to improving physical performance in 15-a-side rugby union may have little applicability to rugby sevens. It is reasonable to conclude physical preparation for the rugby sevens player should differ from that of a 15-a-side rugby union player and reflect the unique competition demands. Although the movement patterns of international rugby sevens players have been reported, further investigation is should seek to understand the individual non-running physical demands and match activities.

Furthermore, whilst comparatively well investigated within other sports, little is understood of the success factors of rugby sevens match play. An understanding of the match skills and actions related to success for rugby sevens teams and individual players would seem of great importance.

Studies reporting the physical characteristics of rugby sevens players have provided understanding of the anthropometrical characteristics of players however the physiological characteristics remain unclear. Future research should seek to investigate differences in physical measures between players from different competition levels as well as between positional groups, which may aid in identifying the relative importance of physical traits. Once identified, the relationship between physical characteristics and on-field success factors can be investigated.

Chapter 3

THE MATCH DEMANDS OF INTERNATIONAL RUGBY SEVENS

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3.0 Prelude

When establishing normative performance profiles and identifying match factors related to success, it is important to first establish the demands of the competition activity, both physical and technical. The Review of Literature in Chapter 2 revealed the current limited availability of data quantifying the competition demands of elite rugby sevens players. Specifically, there currently exists no information on the frequency of match activities of players nor whether differences exist in the running demands of forwards and backs. Understanding the degree to which match demands differ between forwards and backs would provide evidence for whether position-specific match profiles are required. Also of interest in this chapter was whether differences existed in match demands between tournament rounds. This study employed a combination of Global Positioning System (GPS) and event coding in order to describe match demands. The purpose of this study was to provide normative physical and technical match demands of international rugby sevens forwards and backs and to compare the match demands between tournament rounds.

3.1 Introduction

Rugby sevens is an intermittent contact sport played throughout the world. Though played under essentially the same laws and on the same field as 15-a-side rugby union, rugby sevens teams are comprised of seven rather than fifteen players and matches are 14 minutes (20 minutes for Cup finals) as opposed to 80 minutes. Furthermore, rugby sevens is often played in a tournament style consisting of a pool stage and an elimination stage with teams contesting 5-6 games over the course of 2-3 days whereas in 15-a-side rugby union teams generally contest only one match per day and rarely on consecutive days. The IRB Sevens World Series, consisting of 9 tournaments contested by 16-24 international teams, is regarded as the highest level of rugby sevens competition in the world. Importantly, rugby sevens was voted to be included in the Olympic games beginning in 2016.

Time-motion and notational analysis are commonly used within the rugby codes to describe the movement patterns and match activities performed by players [1, 2, 17, 51, 77]. A recent study [1] quantified the position-specific running demands and match activities of 763 international 15-a-side rugby union players, reporting large differences in the match demands of forwards and backs. Investigations of the match demands of rugby sevens players have predominantly been limited to time-motion analysis of running demands [18, 20, 25, 78]with only one analysis including non-running physical demands (tackles, rucks, scrums) and none including counts of activities performed such as passing, carrying the ball, or contesting restarts. Furthermore, only three studies [20, 78, 79] have reported backs and forwards separately, with only one analysing international players. Rienzi et al.[20] reported the running demands of international rugby sevens forwards and backs through video time-motion analysis, however the study was conducted in 1995 making inferences to contemporary players tenuous. No studies have reported the individual match activities of international rugby sevens backs and forwards.

A study of international players competing in both international and domestic tournaments reported small differences (4-39%) in movement patterns between tournament rounds, with most differences occurring in distances covered at a low speed (< 3.5 m-s^{-1}), however the authors did not report whether the team was competing in the cup (top half of teams from pool play) or the bowl (bottom half of teams from pool play) round following pool play. Competing in the cup round as opposed to the bowl indicates a likely greater overall competition level. Furthermore, it is unclear whether differences exist in the frequency of match activities between tournament rounds. An understanding of whether match demands differ as the competition level and match importance increases may have implications for understanding key match statistics.

The aims of the current study were to: (1) present the individual running demands and match activities of international rugby sevens players across an entire IRB Sevens World Series season; (2) determine whether differences exist in the match demands between forwards and backs; and, (3) determine whether differences exist in the match demands between tournament rounds.

3.2 Methods

Match activity and movement data was collected from 27 players from the same international male rugby sevens team who made 406 appearances in 54 matches played in nine tournaments during the 2013 IRB Sevens World Series. Tournaments were contested in Australia, Dubai, South Africa, New Zealand, United States, Hong Kong, Japan, Scotland, and England. The study complied with the ethical standards for observational studies as required by AUT University, New Zealand.

Video analysis software (Sportscode V8.9, Sportstec, Australia) of broadcast video was used to quantify the counts of match activities and ball in play and rest duration. One experienced operator analysed all games. Intra-rater reliability was assessed through coding the same four games one month apart. Intraclass correlation coefficients (ICC) ranged from 0.93 to 1.00 and the typical error of measurement was 0% to 4%. Operational definitions for the match activities used in analysis can be found in Table 3.2.

Ball in play duration was defined as the time from which the ball was put into play; from restarts the time from when the ball was kicked, for scrums from when the forwards engaged, for lineouts when the ball was thrown in, and from tap penalties the time from when the ball was tapped to re-start play. When penalties were taken quickly (≤ 5 seconds from the referee awarding the penalty), play was considered continuous. Rest time was defined as any time between the stoppage and re-start of play, excluding the halftime interval.

Movement data was collected from Global Positioning System (GPS) devices (VX Sport 220, Visuallex Sport international, Wellington, New Zealand) sampling at 4Hz. The GPS device was worn in a fitted vest under the playing jersey. Movement data were described as distances covered across velocity ranges previously used when describing international rugby sevens [18] as well as frequency of sprints ≥ 6 $m\text{-}s^{-1}$ and maximal velocity. GPS devices with a similar sampling rate have shown to be valid and reliable for measuring distances covered and movement speeds [80, 81]. Movement data were only included from players who started and played ≥ 70% of the match. GPS data were collected from 17 players (1-36 files per player) from 50 games. A total of 136 match files were included for analysis. Data were downloaded and analysed using VX View software (Visuallex sport international, Wellington, New Zealand).

3.2.1 Statistical Analysis

Statistical analysis was performed using SPSS software (Version 20, SPSS Inc. Chicago, Ill, USA). As the players in the present study were repeatedly measured over the course of the season, generalized linear mixed modelling was used to account for the lack of independence between observations. The Genlinmixed procedure was used to derive estimated means and standard deviations of running demands and match activities for positional groups and tournament rounds. A negative binomial distribution was used for modelling match activities and sprint frequency, and a normal distribution was used for the running distances covered, with the log link function specified for all analyses. Position and tournament round were included in each model as fixed effects with player included as a random effect. Player match time was included as an offset to account for differences in match duration and for players who do not participate in the entire match. The time offset normalized variables to a per-match, per-round, or per-tournament equivalent, dependent on the analysis.

Magnitude based inferences of the differences between positions and tournament rounds were assessed using the effect size (ES) of the log-transformed means and standard deviations. The following qualitative scale was used to assess the magnitude of differences: 0-0.19 trivial, 0.2-0.59 small, 0.6-1.19 moderate, 1.2–1.99 large, ≥ 2 very large [82]. An effect was deemed unclear if the 90% confidence interval spanned the threshold for both positive (+0.2) and negative (-0.2) effects. Back transformation was used to estimate match activities and running demands in raw units. Ball-in-play and recovery were grouped into the following cycles: 0-15 s, 16-30 s, 31-45 s, 46-60 s, and short (< 45 s), long (>45 s) and very long sequences (>60 s). Differences in the frequency distribution of ball-in-play and recovery cycles was assessed using a proportion ratio with the following qualitative scale (inverse thresholds): <1.11(>0.9) trivial, 1.11-1.43(0.9-0.7) small, 1.43-2.0(0.7-0.4) large, 2.0-3.3(0.3-0.1) very large, 3.3-10(< 0.1) extremely large [83].

3.4 Results

The individual per match and per-tournament running demands and match activities of international rugby sevens backs and forwards are shown in Table 3.1. Trivial differences (ES < 0.2) were observed between backs and forwards for the total distance covered per match and the distance covered at ≥ 5m.s^{-1}. Backs covered a slightly greater total distance at ≥ 6m.s^{-1} (ES = 0.23), performed more sprints (ES = 0.21), and reached a greater maximal velocity (ES = 0.40). When measured over the course of an entire six-match tournament, forwards covered a greater total distance than backs (ES = 0.45) and distance at ≤ 5m-s^{-1} (ES = 0.50) while backs performed a greater number of sprints than forwards (ES = 0.20).

Only small differences were observed in the number of selected match activities performed by backs and forwards per match. Backs performed a greater number of ball carries (ES = 0.31), threw more passes from hand (ES = 0.22), had more line breaks (ES = 0.23), and scored more tries (ES = 0.21). Forwards were involved in a greater number of defensive rucks (ES = 0.26) and had more restart contests (ES = 0.31). Positional roles were more clearly defined when counts of activities performed by backs and forwards over an entire tournament were compared, with clear differences between backs and forwards for all activities excluding missed tackles, handling errors and tries scored. Backs carry and pass the ball more (ES = 0.22 - 0.60) while forwards perform more tackles, are involved in more defensive rucks, and carry more balls into contact (ES = 0.21 - 0.89) (see Table 3.1).

Match demands were similar between the pool and cup rounds with mostly trivial differences observed for both running demands and match activities performed per match (see Table 3.2). As trivial differences were observed for both backs and forwards separately, data is only presented in terms of all players.

The average match time (excluding the half-time interval) for all matches other than cup finals was 15:18 ± 00:40 mins and 21:58 ± 00:44 mins for cup finals matches

(See Table 3.3). The average ball-in-play cycle for all matches was 30.9 ± 23 s while the average recovery cycle was 40.8 ± 22 s. A large increase (ES = 1.5) was observed in the total ball-in-play time from pool round matches to cup round matches with a small increase in the average ball-in-play cycle time (ES = .25) and recovery cycle time (ES = .32) (see Table 3.3). A large increase (ES = 1.5) was observed in the relative proportion of ball-in-play cycles lasting longer than 60 s from pool matches to cup matches (6.3 – 13.6%, pool and cup matches, respectively).

Table 3.1 Individual running demands and match activities for forwards and backs.

Variable	Per 14-min match				Per 6-match tournament*			
	Forwards	Backs			Forwards	Backs		
	Mean ± SD	Mean ± SD	ES ± 90% CL	Qualitative outcom	Mean ± SD	Mean ± SD	ES ± 90% CL	Qualitative outcome
Running demands	(*N* = 39)	(*N* = 97)			(*N* = 11)	(*N* = 14)		
Total distance (m)	1452 ± 243	1420 ± 332	0.14 ± 0.07	Trivial −	9118 ± 861	8774 ± 763	0.45 ± 0.56	Small −
0–5 $m \cdot s^{-1}$ (m)	1202 ± 206	1173 ± 275	0.05 ± 0.03	Trivial −	7480 ± 723	7163 ± 621	0.50 ± 0.45	Small −
≥ 5 $m \cdot s^{-1}$ (m)	252 ± 103	249 ± 130	0.002 ± 0.13	Trivial −	1631 ± 325	1570 ± 316	0.19 ± 0.41	Unclear
Maximal velocity ($m \cdot s^{-1}$)	7.90 ± 0.83	8.40 ± 0.72	0.84 ± 0.49	Moderate +	7.91 ± 0.6	8.38 ± 0.4	0.89 ± 0.73	Moderate +
Match activities	(*N* = 155)	(*N* = 251)			(*N* = 24)	(*N* = 61)		
Ball carries	3.20 ± 2.37	4.11 ± 3.17	0.31 ± 0.15	Small +	20.6 ± 8.48	23.4 ± 10.2	0.33 ± 0.12	Small +
Ball taken into contact	1.59 ± 2.24	1.79 ± 2.85	0.09 ± 0.14	Trivial +	11.3 ± 7.25	9.85 ± 7.58	0.21 ± 0.12	Small −
Passes	2.22 ± 3.32	2.81 ± 5.32	0.22 ± 0.13	Small +	11.7 ± 10.4	16.6 ± 16.3	0.60 ± 0.36	Moderate +
Pass from ground	1.16 ± 0.80	1.41 ± 0.78	0.11 ± 0.13	Trivial +	2.27 ± 2.98	3.05 ± 4.45	0.22 ± 0.13	Small +
Own ruck attended	0.99 ± 1.88	1.02 ± 2.22	0.02 ± 0.70	Unclear	5.53 ± 4.48	6.08 ± 5.66	0.31 ± 0.34	Small +
Tackles	2.68 ± 2.59	2.41 ± 2.52	0.14 ± 0.14	Trivial −	18.1 ± 7.80	14.5 ± 7.01	0.45 ± 0.36	Small −
Missed tackles	0.78 ± 1.00	0.069± 0.95	0.09 ± 0.14	Trivial -	3.05 ± 2.45	2.70 ± 2.34	0.15 ± 0.37	Trivial -
Opposition ruck attended	1.51 ± 1.87	0.89 ± 2.11	0.26 ± 0.13	Small −	7.99 ± 6.76	5.15 ± 5.42	0.89 ± 0.64	Moderate −
Line break	0.36 ± 0.87	0.55 ± 1.32	0.23 ± 0.13	Small +	2.15 ± 2.69	3.27 ± 4.20	0.23 ± 0.13	Small +
Try scored	0.58 ± 0.75	0.74 ± 0.79	0.21 ± 0.11	Small +	2.32 ± 2.62	2.70 ± 3.13	0.13 ± 0.37	Trivial +
Restart take	0.41 ± 1.40	0.19 ± 0.78	0.31 ± 0.21	Small −	2.91 ± 5.58	1.13 ± 0.34	0.45 ± 0.34	Small −
Handling errors	0.62 ± 0.8	0.61 ± 0.78	0.01 ± 0.01	Trivial −	3.40 ± 3.80	3.50 ± 3.70	0.01 ± 0.11	Trivial +
Scrums	1.77 ± 1.86				11.8 ± 6.22			
Lineouts	0.93 ± 1.22				5.78 ± 3.68			

Notes: + or − indicates an increase or decrease from backs to forwards, *N* = number of data files, ES = effect size, CL = confidence limits.
*Includes players who started and contested ≥70% of each match.

Table 3.2 Individual per-match running demands and match activities for all players for Cup and Pool rounds.

	Pool Mean ± SD	Cup Mean ± SD	ES ± 90% CL	Qualitative outcome
Running demands	(N = 78)	(N = 58)		
Total distance (m)	1446 ± 299	1423 ± 285	−0.012 ± 0.25	Trivial −
0–5 $m \cdot s^{-1}$ (m)	1193 ± 251	1180 ± 243	−0.060 ± 0.17	Trivial −
>5 $m \cdot s^{-1}$ (m)	254 ± 123	246 ± 117	−0.094 ± 0.26	Unclear −
Maximal velocity ($m \cdot s^{-1}$)	8.11 ± 0.70	8.22 ± 0.80	0.067 ± 0.27	Trivial +
Match activities	(N = 199)	(N = 207)		
Ball carries	3.51 ± 2.51	3.82 ± 2.57	0.047 ± 0.15	Trivial +
Ball taken into contact	1.60 ± 2.32	1.80 ± 2.51	0.005 ± 0.014	Trivial +
Passes	2.42 ± 3.81	2.51 ± 3.78	0.099 ± 0.042	Trivial +
Pass from ground	0.49 ± 0.98	0.42 ± 1.01	−0.16 ± 0.14	Trivial −
Own ruck attended	1.01 ± 1.83	1.12 ± 1.8	0.02 ± 0.13	Trivial +
Tackles	2.41 ± 2.29	2.72 ± 2.48	0.12 ± 0.14	Trivial +
Missed tackles	0.74 ± 0.99	0.73 ± 0.10	0.001 ± 0.11	Trivial +
Opposition ruck attended	1.25 ± 2.08	0.83 ± 1.74	0.14 ± 0.10	Trivial +
Line break	0.48 ± 0.99	0.43 ± 0.86	−0.084 ± 0.13	Trivial −
Try scored	0.55 ± 0.76	0.70 ± 0.90	0.10 ± 0.16	Trivial +
Restart take	0.30 ± 0.99	0.27 ± 1.01	−0.029 ± 0.21	Trivial −
Handling errors	0.31 ± 0.95	0.45 ± 0.83	0.092 ± 0.18	Trivial +
Scrums*	1.78 ± 1.89	1.83 ± 2.41	0.07 ± 0.18	Trivial +
Lineouts*	0.93 ± 0.85	0.98 ± 0.89	0.08 ± 0.19	Trivial +

Notes: + or − indicates an increase or decrease from Cup to Pool round, N = number of data files, ES = effect size, CL = confidence limits.
*Forwards only.

Table 3.3 Total time, ball-in-play, and recovery cycles for Pool and Cup rounds.

	Pool (n = 27)	Cup* (n = 20)		
	Mean ± SD	Mean ± SD	ES ± 90% CL	Qualitative outcome
Total time (min:s)	15:10 ± 00:41	15:41 ± 00:58	0.65 ± 0.36	Moderate +
Total ball-in-play time (min:s)	6:38 ± 00:34	7:31 ± 01:01	1.50 ± 0.85	Large +
Average ball-in-play cycle (s)	27.8 ± 20.1	33.4 ± 25.1	0.25 ± 0.42	Small +
Average recovery cycle (s)	38.0 ± 21.6	45.2 ± 23.0	0.32 ± 0.19	Small +
Maximum ball-in-play cycle (min:s)	1:56	2:21		
Proportion of ball-in-play and recovery cycle ranges				
Ball-in-play (s)	%	%	Proportion ratio (Pool/Cup)	Qualitative Outcome
0-15	35.4	27.5	1.28	Small -
16–30	26.4	27.7	0.95	Trivial +
31 –45	21.9	19.4	1.12	Small −
45–60	10.1	11.8	0.85	Small +
>60	6.3	13.6	0.46	Large +
<45	83.7	74.6	1.12	Small −
>45	16.3	25.4	0.64	Moderate +
Recovery (s)				
0–15	7.5	8.1	0.93	Trivial +
16–30	39.9	30.3	1.32	Small −
31–45	17.9	20.6	0.87	Small +
46–60	14.6	15.0	0.97	Trivial +
>60	20.1	25.9	0.80	Small +
<45	65.3	59	1.1	Trivial −
>45	34.7	41	0.8	Small +

3.5 Discussion

The primary purpose of this study was to describe the individual running demands and match activities of international rugby sevens players. The results of this study expanded on previous investigations of the match demands of rugby sevens players [18, 25, 78, 79] through the inclusion of the frequency of non-running activities performed. Over the course of a tournament, starters can expect to run ~9km, carry the ball ~20 times, and are involved in ~30 rucks and tackles.

A key finding of the present study was the absence of substantial differences in the overall match demands of international rugby sevens forwards and backs. Per-match differences between backs and forwards were small for all running variables and match activities. Backs perform more high-speed movements and handle and pass the ball more frequently while forwards engage in more contact situations. A lack of clearly defined positional roles on a per-match average is owed in part to the high between-match variability (CV 29 - 409%) in running demands and activities performed. The variability in total-tournament running demands and match activities, whilst still high, decreased (CV 9 - 131%), however no large differences in the match demands of forwards and backs were observed. The lack of clearly defined positional roles in rugby sevens is in stark contrast to international 15-a-side rugby union in which it has been revealed large differences (ES > 1.2) exist in the majority of movements and activities performed by backs and forwards [1]. Forwards in 15-a-side rugby union are generally defined by their increased involvement in contact situations (scrums, rucks, and tackles), however in rugby sevens forwards and backs are involved in a similar amount of contact situations throughout a match. Researchers investigating 15-a-side rugby union [1, 2, 4] have suggested that physical preparation should be position-specific for forwards and backs to account for vastly different match demands, however it appears a more general approach may be applied to rugby sevens players. Furthermore, it would seem given a lack of practically important differences in the match demands between forwards and backs, the need for position specific physical testing for rugby sevens may not be required, as has been previously shown through the low variability (CV = 2.5 - 11.9%) in performance measures across an international rugby sevens team [29].

It appears the total match demands as well as the position–specific match demands differ between international and domestic competition. The relative distance covered across all positions was 106 $m.min^{-1}$ in the present study, somewhat lower than previously reported values for international [18] players (113 m-min^{-1}) and similar to domestic players (102 m.min^{-1}). It appears running demands may be more position-specific in domestic competition as the relative distance covered by international forwards (108 m.min^{-1}) in the present study was higher than that reported for domestic forwards (98 m.min^{-1}), while an opposite result was found when comparing backs, with international players (103 m-min^{-1}) covering a smaller distance than domestic players (107 m.min^{-1}) [79].

The total number of tackles reported by Suarez-Arrones et al. [79] is substantially greater than identified in the present study, with forwards and backs involved in ~112% and ~33% more tackles, respectively. Beyond differences in competition level, it seems plausible that teams of different rank within the same competition will have different match demand profiles, though no studies exist within rugby sevens to confirm this contention. It is also worth noting that recent investigations [18, 25, 78, 79]of the match demands of rugby sevens players have repeatedly measured a generally small sample of players (n = 5 – 17) whilst employing statistical methods that do not account for the lack of independence between observations, which may result in outcomes being biased towards players providing more observations. Methodological differences notwithstanding, it appears the overall match demands of international rugby sevens may differ from domestic competition, though further research is required to understand the factors that differentiate different levels of competition and teams in rugby sevens.

As previously noted, the match-to-match variability in running demands and activities performed is high; however, in agreement with previous research [18] running demands were similar across a tournament while differences in the activities performed were mostly trivial and small. Interestingly, though running demands and match activities were similar between tournament rounds, a large (ES = 1.5) difference in the average ball-in-play time and a large increase (proportion ratio = 0.46) in the number of ball-in-play sequences > 60s was observed from the cup as compared to the pool round. However, the increase in the average activity sequence in cup round matches is coupled with an increase in recovery time between efforts resulting in a similar work: rest ratio between rounds. The lack of clear differences in activities performed between pool and cup rounds may suggest a relatively stable overall competition level, however further investigation is required to determine the match activities of importance in international rugby sevens.

A unique aspect of international rugby sevens competitions is the increase in match duration for the cup championship (2 x 10 min halves) compared to all other matches. The increase in match duration during cup finals (n = 7) resulted in a 35% increase in distance covered, and a 55% increase in the number of tackles made. However, when compared on a standardized per-match average, all differences between 14 and 20-minute matches were trivial to small, suggesting that despite the match being contested by the two top performing teams in the tournament, relative match demands do not differ substantially.

The per-match average contact loads and distances covered for backs and forwards in international rugby sevens are relatively low when compared to international 15-a-side rugby union. It would seem important however, to consider total-tournament match demands when considering recovery in rugby sevens. When compared to an 80 minute 15-a-side rugby union match, over the course of a tournament rugby sevens starters cover ~51% and ~82% greater total distance, (backs and forwards respectively), while rugby sevens backs are involved in ~40% more total contacts, suggesting that post-tournament fatigue may be higher in rugby sevens players than some 15-a-side rugby positions. Investigations within 15-a-side rugby union and rugby league have shown post-match fatigue is mediated by match specific demands, however no studies have investigated post-tournament fatigue and recovery in rugby sevens.

3.6 Conclusion

This was the first study to present the total match demands and positional roles of international rugby sevens players. In contrast to 15-a-side rugby union, positional roles for backs and forwards were not clearly delineated, suggesting preparation for rugby sevens can take a more generalist approach across positions for physical and technical and tactical preparation. While further investigation with a greater number of teams is warranted, it appears the match demands of domestic and international rugby sevens differ substantially. International level matches appear to involve fewer contact situations than domestic matches though running demands appear similar. Despite a large match-to-match variability in the frequency of tasks performed, match demands differed little between the pool and cup round, and between finals and non-finals matches. It should be noted that the data collected from the present study was from one international rugby sevens team. Consequently, the findings in this study may not be applicable to all international rugby sevens teams in general and may be influenced by the tactics, talent level, and experience of the players on the team. Further research with a larger sample of international teams is required.

3.7 Practical Applications

The lack of clear differences in running demands and activities performed by backs and forwards suggest position-specific physical preparation and assessment may not be required for international rugby sevens players. Further, rugby sevens is played at a substantially greater intensity than 15-a-side rugby union and as such training should seek to acknowledge this greater intensity. When considering the recovery needs of rugby sevens players, total-tournament loads as opposed to single game loads should be considered.

Chapter 4

A COMPARISON OF THE MATCH DEMANDS OF INTERNATIONAL AND PROVINCIAL RUGBY SEVENS

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4.0 Prelude

Rugby sevens is contested across a wide range of competition levels, from amateur to elite international players. One method in which to determine physical and technical factors of importance to elite rugby sevens is to compare the match demands of elite and sub-elite players. The previous chapter (Chapter 3) identified similarities in the match demands of international rugby sevens forwards and backs, while match demands remained largely similar throughout tournaments. Understanding the factors that distinguish elite and sub-elite rugby sevens matches should provide further information for the design of strength and conditioning and technical/tactical programs and may aid with informing talent identification, player selection, normative match profiles, and match performance analysis. Similar to the previous section, this chapter utilized event coding and GPS tracking to compare the technical and physical match demands of international and provincial rugby sevens players, and also compared the work to recovery ratios of the two competition levels. The purpose of this chapter was to compare the running demands and match activities of international and provincial rugby sevens players.

4.1 Introduction

Rugby sevens is an international sport contested across different playing standards, from youth and amateur levels to international. Whilst played under essentially the same laws and on the same playing field as rugby union, rugby sevens is contested with seven players per team. Competitions are most often played in a tournament fashion, with teams contesting five to six fourteen-minute games per tournament. Recent investigations have described the running demands of players competing in international [18, 84, 85] and domestic level matches. The game-specific actions are considerably less known with no studies to date describing the individual skill demands, with other studies describing the team match demands [19, 24, 86]. With rugby sevens to be introduced to the Olympics beginning in 2016, it seems likely countries will seek to introduce development pathways to prepare players for international rugby sevens. It would appear important then to have an understanding of the differences in match demands between different levels of rugby sevens competition to assist and guide the development of the International sevens player.

Notational analysis of match video together with Global Positioning System (GPS) analysis is a useful method to describe the match demands and activities performed in team sport athletes [1, 51, 87]. Analyses of the physical demands of rugby sevens matches have largely focused on the movement patterns of players via GPS units [18, 25] with notational analysis limited to quantifying the frequency of tackles in domestic matches [79]. Players competing in international matches have been shown to cover a relative distance of between 96 -120 $m.min^{-1}$ [18, 84] with domestic level players covering a relative distance of between 98 -108 $m.min^{-1}$ per match . However, differences in methodology, sample size, and variables reported between studies makes more in-depth comparisons between competition levels problematic. One study [18] to date has directly compared the match demands of international and provincial rugby sevens, reporting mostly small and trivial differences in the running demands between international and provincial tournaments, however, the same international level players were analysed at each tournament level. As it is likely that international players possess greater physical capacities than domestic level players, an international player competing at domestic level may not provide an accurate estimation of the true match demands at the provincial level.

Understanding the movement demands of rugby sevens is of value when designing training programs and drills. It is also of importance to understand the game-specific activities performed by players during a match, both to quantify the total physical load and understand the frequency at which various tasks are performed. Furthermore, understanding differences in the frequency and technical execution of tasks performed during a match can inform player development and match-specific training. No study to date has reported the individual game-specific demands of international or provincial rugby sevens matches.

Knowledge of the differences in match demands between different levels of competition can aid in informing the requirements for players to transition between levels. Furthermore, match variables that show a large difference between levels of competition are likely to aid in informing match success factors. Given the lack of a clear understanding of the differences in match demands between international and provincial rugby sevens, the aim of this study therefore was to identify differences in the running demands, match activities, and temporal sequences between the two competition levels through a combination of GPS and notational analysis.

4.2 Methods

Sixteen international rugby sevens players from the same team and 68 provincial level rugby sevens players from eight teams participated in this study. GPS was collected from 11 international players and 12 provincial level players while match activity data was collected from all players. Informed written consent was collected from all players. The ethics committee for AUT University, New Zealand approved the study.

GPS data was collected from international players during IRB Sevens World Series tournaments in Australia, Dubai and South Africa. Data from provincial level players was collected during the national provincial rugby sevens championship and regional qualifying tournaments. Players wore GPS units (VX230, VXsport, Wellington, New Zealand) sampling at 4 Hz in fitted garments under their playing jersey. Similar GPS units have been shown to be reliable for describing the distances and speeds of team sport athletes, however caution must be used when interpreting results of high-speed activities [88]All data was analysed through the same version of software provided by the manufacturer (Vx View Version 3.22, Vxsport, Wellington, New Zealand).

Data from the GPS units was classified into relative distance (m.min^{-1}), low speed running [LSR] (< 4.16 m.s^{-1}), high-speed running [HSR] (≥ 4.16 m.s^{-1}), and very high-speed running [VHSR] (> 6 m.s^{-1}), which represent speed thresholds previously used in rugby sevens match analysis. To account for differences in time played, all match activity and movement data was expressed per minute. A total of 37 match files from 12 provincial players and 92 match files from 11 international players were included in the analyses.

Match activity data was collected through analysis of broadcast games using video analysis software (Sportscode V8.9, Sportstec, Australia). One experienced operator analysed all games. Intra-rater reliability was assessed through analysing the same four matches one month apart, with intraclass correlation coefficient (ICC) for the test-retest showing acceptable reliability (0.85 – 1.00) [89]. The operational definitions of the match activities used in analysis are shown in Table 4.1.

Table 4.1 Operational definitions of match activities of international and provincial rugby sevens players

Ball carry	Count of times the player advances a minimum of three steps toward the defence while in possession of the ball
Total passes	The player passes the ball
Ineffective passes	The player passes the ball and misses their target
Total tackles	The player is involved in a tackle in defence
Effective tackles	The player is involved in a tackle in a turnover, dominant, or effective tackle
Ineffective tackles	The player is involved in a passive, offload allowed, or missed tackle
Total rucks	The player is involved in in an attacking or defensive ruck
Own ruck attended	The player is involved in support in an attacking ruck
Opposition ruck attended	The player is involved in in an opposition ruck
Effective counter	The player is involved in an effective counter ruck
Ineffective counter	The player is involved in an ineffective counter ruck
Defensive ruck effectiveness	Proportion of defensive rucks attended in which the player makes an effective counter

All match activity and GPS values are expressed relative to match time and only players who contested greater than six minutes per match were included in analysis. A total of 96 match files were collected from 68 provincial players and 92 match files from 14 international players.

Ball-in-play and recovery cycles were collected from each game to assess match temporal differences between the two levels of competition. Ball-in-play cycles were described as any period in which play was active with recovery cycles including any stoppages in play with the exception of the half time interval. For instances in which a team restarted play within five seconds of being awarded a penalty, this was not considered a stoppage.

4.2.1 Statistical analysis

Descriptive statistics (mean ± SD) of running demands and match activities were derived through a linear mixed model. Prior to analysis, movement data was log transformed and match activity data square root transformed to reduce the non-uniformity of error [90]. For each analysis, competition level (international or provincial) was included as a fixed effect while player i.d. was included as a random effect. The standardized difference in the mean was used to determine differences in match demands between international and provincial rugby sevens players established with the pooled between-subject SD used for standardization [90]. The magnitude of each effect was assessed using a qualitative scale with the following thresholds: 0-0.19 trivial, 0.2-0.59 small, 0.6-1.19 moderate, 1.2-1.99 large, > 2.0 very large [82] Differences in the proportion of ball-in-play and recovery cycles between international and provincial matches was assessed using a proportion ratio with the following qualitative scale (inverse thresholds): <1.11 (>0.9) trivial,1.11-1.43 (0.9-0.7) small, 1.43-2.0 (0.7-0.4) large, 2.0-3.3 (0.3-0.1) very large, 3.3-10 (< 0.1) extremely large [83].

4.3 Results

The low speed running demands of international and provincial players were similar with trivial differences observed between the two competition levels in relative distance and distance covered at low speed (Table 4.2). International players performed a substantially 25% greater frequency of efforts at VHSR (ES = 0.80) with a resultant 15% greater VHSR distance covered (ES = 0.30). No clear differences were identified between the two groups in the distance covered at LSR and HSR (ES = 0.02 – 0.12).

Small to moderate differences were observed in the frequency of all match activities with the exception of the total number of tackles affected (Table 4.2).

International players performed a greater number of ball carries and completed a greater number of passes while provincial players had more ineffective passes (ES = -0.49) and committed more handling errors (ES = -0.29). The quality of tackles varied between the groups with international players completing a greater number of effective tackles (ES = 0.26) and provincial players a greater number of ineffective tackles (ES = -0.24). Similarly, international players attended a greater number of total, attacking, and defensive rucks whilst performing a greater number of effective defensive counter rucks (ES = 0.54) and a fewer number of ineffective counter rucks (ES -0.33).

Table 4.2 Individual running demands and match activities for provincial and international rugby sevens players

	Provincial	International		
	Mean ± SD	Mean ± SD	ES ± 90% CL	Qualitative outcome
Running demands	(n=37)	(n=92)		
Relative Distance (m min^{-1})	105 ± 13.8	105 ± 12.0	0.03 ± 0.34	Unclear
LSR (m min^{-1})	76.8 ± 7.78	77.8 ± 8.38	0.12 ± 0.29	Trivial +
HSR (m min^{-1})	27.9 ± 9.19	26.9 ± 7.25	0.02 ± 0.26	Unclear
VHSR (m min^{-1})	8.35 ± 4.38	9.80 ± 4.43	0.30 ± 0.32	Small +
Sprints > 6 m-s^{-1} (n min^{-1})	0.45 ± 0.18	0.60 ± 0.19	0.80 ± 0.33	Moderate +
Match activities	(n = 96)	(n = 92)		
Ball carries (n min^{-1})	0.26 ± 0.16	0.30 ± 0.16	0.28 ± 0.24	Small +
Passes (n min^{-1})	0.25 ± 0.19	0.34 ± 0.28	0.34 ± 0.25	Small +
Ineffective passes (n min^{-1})	0.04 ± 0.06	0.02 ± 0.04	-0.49 ± 0.20	Small -
Handling errors (n min^{-1})	0.03 ± 0.05	0.02 ± 0.04	-0.29 ± 0.25	Small -
Total tackles (n min^{-1})	0.19 ± 0.13	0.20 ± 0.15	0.07 ± 0.31	Unclear
Effective tackles (n min^{-1})	0.08 ± 0.08	0.11 ± 0.09	0.26 ± 0.24	Small +
Ineffective tackles (n min^{-1})	0.08 ± 0.08	0.07 ± 0.09	-0.24 ± 0.24	Small -
Total rucks (n min^{-1})	0.12 ± 0.12	0.20 ± 0.16	0.52 ± 0.24	Small +
Attacking rucks (n min^{-1})	0.07 ± 0.09	0.12 ± 0.11	0.48 ± 0.24	Small +
Defensive rucks (n min^{-1})	0.05 ± 0.07	0.08 ± 0.10	0.23 ± 0.24	Small +
Effective counter rucks (n min^{-1})	0.03 ± 0.06	0.07 ± 0.09	0.54 ± 0.27	Small +
Ineffective counter rucks (n min^{-1})	0.02 ± 0.04	0.01 ± 0.03	-0.33 ± 0.23	Small -
Defensive ruck effectiveness (%)	53%	83%	0.64 ± 0.25*	Moderate +

+ or – indicates an increase or decrease from provincial to international matches, n= number of match files, ES = Effect size, CL = Confidence limits
*Proportion ratio (provincial/international)

International matches had an average total duration of 16:11min, an average (mean) of 38 seconds longer than provincial matches (

Table 4.3). As well, international matches had a ~13% longer total ball-in-play duration and a ~15% greater average ball-in-play cycle (ES = 1.32), with no differences between the two groups in average recovery cycle (ES = 0.04).

Differences were also observed in the proportion of ball-in-play cycles, with international matches displaying a ~11% greater proportion of long (>45s) and ~7% greater very long (>60s) ball-in-play cycles. Conversely, provincial matches had a greater frequency of short duration (<30s) ball-in-play cycle.

Table 4.3 Total time, ball-in-play, and ball-in-play cycles for provincial and international matches

	Provincial	International		
	Mean ± SD	Mean ± SD	ES ± 90 % CL	Qualitative outcome
Total time (min:s)	15:33 ± 55.8	16:11 ± 42.6	1.12 ± .72	Moderate +
Total ball-in-play time (min:s)	6:43 ± 32.4	7:36 ± 43.8	1.32 ± .72	Large +
Average ball-in-play cycle (s)	29.4 ± 22.0	34.4 ± 23.7	0.21 ± .19	Small +
Average recovery cycle (s)	41.9 ± 20.3	41.6 ± 17.6	0.04 ± .21	Trivial +
Proportion of ball-in-play cycle ranges				
Ball-in-play (s)	%	%	Proportion ratio (Provincial/International)	Qualitative outcome
0 – 15	30.3	23.3	1.30	Small +
16 – 30	29.0	32.7	0.88	Small -
31 – 45	23.9	16.7	1.43	Small +
45 – 60	7.7	11.3	0.68	Moderate -
> 60	9.0	16.0	0.56	Moderate -
< 45	83.2	72.7	1.14	Small +
> 45	16.8	27.3	0.62	Moderate -

+ or – indicates an increase or decrease from provincial to international matches, n = number of matches, ES =Effect size, CL = Confidence limit

4.4 Discussion

The purpose of this study was to characterize and compare the match demands of international and provincial rugby sevens. It can be observed from the results that the competition level of rugby sevens is associated with practically important differences in running, technical and temporal factors. Specifically, international players cover a larger distance at very high speeds and are involved in a greater number of rucks. International matches also involve substantially greater active cycles than provincial matches. The relative distance covered by both international and provincial level players in the present study ~105m.min^{-1} is somewhat greater to that reported in recent investigations of international (96-103 m.min^{-1}) and domestic level players (~102 m.min^{-1}) [18, 25, 78, 79, 84]. It is worth noting the international team analysed in the present study was currently ranked number one in the world at the time data was collected.

Whilst overall relative running demands were similar between the two levels (105 m.min^{-1}), international players covered a greater total distance at very high speeds with no substantial differences between the groups in LSR and HSR distance covered. The increase in sprint distance covered between the levels of play is likely explained by a multitude of factors. International players are likely to possess greater speed characteristics than provincial level players and thus able to reach higher velocities within matches. The ability to withstand fatigue within a match may also partially explain the differences in sprinting. Conversely, differences in skill execution and a decrease in the frequency of handling errors in international games may possibly afford players greater opportunities to reach high speeds. While the physical traits of international level rugby sevens players have been investigated [29] further research is required identifying the differences in physical characteristics between rugby sevens players of different ability levels.

In contrast to the mostly similar running demands between the two levels and in observations in rugby league [51] differences were observed in nearly all match activities between the two levels of play. International players display superior ball handling to provincial level players as evidenced by a greater number of poor passes and handling errors committed by provincial level players despite fewer pass attempts. Whilst players from both levels affect a similar number of total tackles, international players display superior tackle ability with a greater number of effective tackles and fewer ineffective and missed tackles. International players are likely to possess greater muscular power than provincial level players which has been shown to be related to tackling ability in rugby league [61]. The greater proportion of effective counter rucks by international players may also likely be partially explained by differences in muscular power and strength, whilst it is also possible that the ability to resist fatigue throughout a match may contribute to the effectiveness of defensive ruck contests. Further research of the relationship between physical fitness and match performance in rugby sevens is warranted. Conversely, a greater technical and tactical acumen amongst international players may also explain their greater efficiency in the defensive ruck.

Interestingly, international matches encompass a greater frequency of long duration activity cycles and overall ball-in-play time however, the relative distance covered during a match is nearly identical to provincial players despite all time spent on the field regardless of ball-in-play status included in analysis. There likely exists a relationship between attacking skill execution and an increase in ball-in-play cycle duration, as ineffective passes and handling errors are likely to result in match stoppages whilst a greater frequency of completed passes would likely reduce the amount of running performed by players.

Furthermore, international players likely possess greater tactical awareness, which may improve their match running efficiency. Indeed, it appears many of the differences in match variables between the two levels of play are likely interrelated and explained by a multitude of factors such as physical fitness, skill execution, tactical acumen, and playing experience. For instance, the lower frequency of handling errors by international players may be related to an increased skill level, a greater ability to withstand fatigue, and better decision-making ability [77].

Whilst analysis was limited to the entire match in the present study, differences in running demands and match activities between different levels of rugby sevens is warranted as previous research of domestic[25]and international [18] rugby sevens players has shown decreases in distances covered from the first to the second half of a game. Furthermore, future rugby sevens match analysis should seek to incorporate physiological measures such as heart rate to GPS and notational analysis to provide both a global understanding of match demands as well as the relationship between external loads (running, tackling, rucking, and mauling) and internal loads [91].

4.5 Conclusion

This study reported for the first time the differences in total match demands between international and provincial rugby sevens players. International and provincial players experience similar running demands during matches, with international players performing a greater quantity of very high speed running (> 6 $m.s^{-1}$). Substantial differences were observed in the frequency and execution quality of many match activities between the two levels, with international players performing more effective tackles and committing fewer handling errors. The average duration and frequency of long duration ball-in-play cycles is considerably higher in international matches than in provincial matches, likely related to the lower frequency of handling errors. The results of this study have implications for the design of training programs for international and provincial rugby sevens players as well as for informing the establishment of match success factors.

Chapter 5

A COMPARISON OF THE ANTHROPOMETRIC AND PHYSICAL CHARACTERISTICS OF INTERNATIONAL AND PROVINCIAL RUGBY SEVENS PLAYERS

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5.*0 Prelude*

In Chapter 4 the demands of international and provincial rugby sevens matches were compared, with the main findings being international players sprinted more throughout a match and executed skills more accurately, while also experiencing longer ball-in-play sequences. It would appear based on the results of previous chapters, the running demands of rugby sevens require players to possess well developed speed and aerobic capacity levels while the contact and collision demands highlight the need for players to also possess muscular strength and power. However, without knowing the anthropometric and physical characteristics of rugby sevens players this remains presumptive. Furthermore, identifying the anthropometric and physical characteristics that distinguish between rugby sevens players of different competition level may provide useful information for strength and conditioning coaches when determining the relative importance of developing different physical qualities. The purpose of this chapter was firstly to investigate the magnitude of differences in anthropometrical and physical characteristics of international and provincial rugby sevens players and secondly to compare the anthropometrical and physical characteristics of forwards and backs.

5.1 Introduction

Rugby sevens is an intermittent, field-based collision sport played at various competition levels from recreational to international. The game is played under essentially the same laws and on the same size pitch as 15-a-side rugby union (rugby union) however, matches are contested by seven players per team. Given the increased relative playing area available to players, rugby sevens is played at a considerably greater relative intensity when compared to rugby union [18], with players covering a relative distance of approximately 100-120 $m.min^{-1}$ match compared to approximately 70-80 $m.min^{-1}$ in rugby union [4, 18]. Rugby sevens players also engage in more frequent contact situations including rucks, tackles and scrums per unit time than rugby union backs Furthermore, the tournament nature of rugby sevens competition induces high levels of fatigue and muscle damage [92] placing a greater emphasis on between-match recovery. As a result of the high running and contact demands, in addition to the relatively short rest intervals between matches, rugby sevens players must possess an array of well-developed physical qualities such as strength, speed, power and aerobic endurance [29].

Studies reporting the physical characteristics of rugby sevens players are scarce [29, 92, 93]. Higham et al. [29] reported mean sprint times of 1.74 s for 10 m and 5.11 s for 40 m for 17 international players from the same team, with 10 m sprint times similar to those reported for professional rugby union backs (1.69 – 1.73 s) [5, 9]. The maximal oxygen uptake (VO_{2max}) of the players was reported as 53.8 L.min-1, while the players achieved a mean distance of 2256 m in the Yo-Yo intermittent recovery test level one. Investigations reporting the power characteristics of rugby sevens players has reported international players produce peak power in a countermovement jump of ~5400-5700 w [92, 93]. However, the strength characteristics of rugby sevens players remain unknown.

Investigations within rugby union [5, 9, 34] have revealed large differences in the anthropometrical and physical characteristics of backs and forwards, with forwards typically being taller, heavier, and possessing greater absolute upper body and lower body strength and power, whilst backs are generally leaner, faster and possess greater aerobic power. Forwards in rugby sevens are also taller and heavier than backs, while the magnitude of difference between the positions is less than in rugby union [5, 30]. However, differences in physical characteristics between playing positions (forwards and backs) within rugby sevens remain unknown as in the previously mentioned study [29] players were not grouped by position. Whilst comparisons of the match demands of rugby sevens forwards and backs have revealed mostly trivial and small differences [79, 84, 85], it seems plausible differences may still exist in the strength, speed, power, and aerobic endurance characteristics of the two groups.

With rugby sevens inception in the 2016 Olympics, many countries are likely to have an interest in developing talent identification and development pathways to progress players. An understanding of the differences in characteristics between players of different competition level would aid in informing these pathways. However, to date, no study has compared the physical characteristics of elite and sub-elite rugby sevens players. With this in mind, the aims of this study were firstly to compare the anthropometrical and physical characteristics of international and provincial rugby sevens players, and secondly to compare the anthropometrical and physical characteristics of rugby sevens forwards and backs.

5.2 Methods

To compare the physical characteristics of different levels of rugby sevens players, participants from provincial and international rugby sevens teams volunteered to participate in this study. To ensure players were in a trained state, all testing was performed within one month of the National Provincial Rugby Sevens Championship tournament for provincial players and within one month of an International rugby Board (IRB) Sevens World Series tournament for the international team. All players were familiar with the testing protocols and had experience with all assessments and as such familiarization was not required. Testing was performed in two sessions, with the first session consisting of speed, power and repeated speed assessments and the second session upper body strength and aerobic fitness. Sufficient recovery time was provided to players between tests in order to ensure maximal effort was given in each test. Players were asked to consume a normal diet and refrain from strenuous activity for a minimum of 24 hours prior to testing. When comparing forwards and backs, the primary playing position of each player was assessed as in some cases players played both as a forward and back.

A total of 65 rugby sevens players; 43 provincial players (N = 25 backs; N = 18 forwards) from four teams and 22 international players (N = 12 backs; N = 10 forwards) from the same team were involved. The provincial players were from teams competing at the New Zealand National Provincial Rugby Sevens Championship tournament, the highest level of domestic rugby sevens competition, while the international team was a core member of the IRB Sevens World Series. Subject characteristics are provided in Table 5.1. Informed written consent was obtained from all players and the AUT university ethics committee provided ethical approval.

5.2.1 Anthropometry

Body mass and body composition were collected according to the International Society for the Advancement of Kinanthropometry (ISAK) guidelines by an ISAK accredited anthropometrist [94]. Body mass was measured on a calibrated digital scale. Height was measured using a stadiometer. Body composition was quantified via the sum of eight skinfolds (tricep, biceps, subscapular, abdominal, supraspinale, iliac crest, front thigh and medial calf). All intra-rater anthropometrical technical errors of measurement were below the recommended limits [95].

5.2.2 Speed

Speed was assessed indoors on an artificial (track) running surface. Players performed a maximal effort sprint over 40 m. Prior to performing the sprint, players completed a 15 minute warm up consisting of five minutes of light jogging, 5 minutes of dynamic stretches for the lower limbs e.g. skipping, bounding, high knee running, and finished with three sprints over 40 m at 70%, 80%, and 90% intensity. Dual-beam electronic timing gates (Speedlight TT, Swift Performance Equipment, Lismore, Australia) were placed at 0, 5, 10, and 40 m distances. Players commenced sprints 0.3 m behind the starting gate from a crouched, split standing start with no countermovement. Speed at each split was recorded to the nearest 0.01 s. Participants performed two sprints with five minutes of passive rest interspersed between efforts. Each participant's fastest sprint was used for analysis. The coefficient of variation for sprint times under similar protocols has been shown to be 1.9 – 2.0% [96].

5.2.3 Power

Vertical power was obtained from players performing a maximal countermovement jump (CMJ) whilst holding a 1 kg pole for the bodyweight condition and a 50 kg barbell for the loaded condition. Lower body peak power was assessed by a linear position transducer (Gymaware, Kinetic Performance, Australia) affixed to the pole or bar. Players were asked to lower to a self-selected depth and rapidly jump as high as possible whilst maintaining hold of the pole or barbell. Following a familiarization of three practice jumps, players were given two trials of three jumps with three minutes passive rest between trials, with the highest value recorded by each player included in analysis.

Relative power ($w.kg^{-1}$) was also calculated by dividing each participants peak power by their mass. The coefficient of variation for peak power using the described methods has been shown to be 2.3% [97]. Horizontal power was indirectly measured through a countermovement horizontal jump. Participants performed three practice jumps to familiarize themselves with the test procedures after which three maximal countermovement jumps with two minutes rest between trials were recorded for analysis. Jump distance was measured from toe off to the back of the hindmost foot to the nearest cm. Participants were required to "stick" the landing in order for the jump to be included in analysis. The coefficient of variation for the countermovement horizontal jump has been shown to be 2.4% [98].

5.2.4 Repeat Sprint Ability (RSA)

To assess RSA, players performed a maximal 10 x 40 m sprint test. The test was performed indoors on an artificial running surface with players starting 0.5 m behind the electronic timing gates. Players ran back and forth between the timing lights, departing each sprint on a 30 s cycle. Average (mean) sprint time across the ten sprints were measured to the nearest 0.01 s. Participants were verbally encouraged to provide a maximal effort on each sprint. The coefficient of variation for similar repeat sprint assessment has been shown to be 1.9% [99].

5.2.5 Upper-Body Strength

Upper-body strength was quantified via 2-5 repetition maximum (RM) assessments in the bench press and weighted reverse grip chin up. For the bench press, players used a self-selected grip width and were required to lower the bar to chest level with feet to remain in contact with the floor at all times. For safety purposes a spotter was used, however a lift was excluded from analysis should the spotters hands come into contact with the bar during the lift. Players began the chin up with arms extended and were required to raise themselves to where their chin was over the bar. A belt was used to load external resistance. Players were instructed to progressively increase resistance on each exercise until they were unable to perform more than five repetitions. One repetition maximum (1RM) from the lifts was calculated from the following formula: 1RM = (100xweight)/(101.3 – (2.67123xreps)) [100], with the coefficient of variation for the bench press and chin up using similar protocols has been shown to be 1.5% and 2.6%, respectively [96].

5.2.6 Maximal Aerobic Capacity

The 20 m multistage fitness test (MSFT) was used to assess the aerobic capacity of players [101]. Players were required to run back and forth along a 20 m track in time with ‘beeps’ emitted from a stereo. The required speed of each shuttle gradually increased over the course of the test and players were required to run until they were no longer able to keep in time with the beeps. The final level and shuttle reached was converted to total distance covered (m) by each player for analysis. The test-retest reliability for the MSFT has been shown to be 3.5% [96].

5.2.7 Statistical Analyses

All data are reported as mean ± standard deviation (SD). Analyses were performed using a custom spreadsheet to compare groups [102]. Strength, power, and aerobic fitness data was log transformed to reduce the non-uniformity of error and back transformed to produce differences between playing levels and positions as a percent [90]. Speed measures were compared without transformation.

Standardized differences in the mean between groups were assessed by dividing the change by the pooled between-subject SD and assessed according to a modified Cohen scale with standardized changes of: 0-0.19, 0.20-0.59,0.60-1.19,1.20-1.99, ≥ 2.0 representing trivial, small, moderate, large, and very large differences, respectively [82]. Uncertainty in the effect size (ES) was described with 95% confidence limits. A difference between groups was deemed unclear if the confidence limit for the effect crossed the threshold for both substantially positive ≥ 0.20 and negative effects ≤ -0.20 [82].

5.3 Results

5.3.1 International vs. provincial players

The age, anthropometrical and physical characteristics of the international and provincial rugby sevens players are shown in Table 5.1. Substantial (ES = 0.58 – 2.26) differences were observed in age and all physical characteristics. Large differences (ES > 1.20) were observed between the two levels in 40 m sprint time (4.5%), body mass (32%) and 50 kg CMJ peak power (25%), weighted reverse grip chin up strength (16%), and MSFT distance (19%). A very large (ES > 2.00) difference was observed for RSA (-5.6%).

Table 5.1 Age and physical qualities of international and provincial rugby sevens players

	Provincial (n = 43)	International (n = 22)			
	Mean ± SD	Mean ± SD	% Difference ± 95% CL	ES ± 95% CL	Qualitative outcome
Age	21.2 ± 3.36	24.0 ± 3.71	13 ± 9.0	0.81 ± 0.53	Moderate +
Height (cm)	182 ± 4.86	186 ± 5.74	2.3 ± 1.6	0.83 ± 0.57	Moderate +
Mass (kg)	89.1 ± 9.45	95.7 ± 7.06	9.0 ± 4.7	0.97 ± 0.48	Moderate +
Sum of skinfolds (mm)	73.8 ± 15.5	61.6 ± 10.5	-16 ± 10	-0.87 ± 0.62	Moderate -
5m (s)	1.02 ± 0.06	0.99 ± 0.03	-2.8 ± 2.6	-0.57 ± 0.54	Small -
10m (s)	1.73 ± 0.08	1.68 ± 0.05	-3.1 ± 1.8	-0.83 ± 0.48	Moderate -
40m (s)	5.23 ± 0.18	4.99 ± 0.11	-4.4 ± 1.3	-1.56 ± 0.48	Large -
10 x 40m Average (s)	5.76 ± 0.14	5.43 ± 0.13	-5.7 ± 1.6	-2.33 ± 0.67	Very large -
Horizontal jump (cm)	2.52 ± 0.18	2.66 ± 0.11	5.8 ± 2.8	0.95 ± 0.45	Moderate +
BW CMJ peak power (w)	6422 ± 726	8600 ± 1692	32 ± 13	1.64 ± 0.60	Large +
BW CMJ relative power (w/kg^{-1})	72.1 ± 11.3	88.8 ± 13.7	23 ± 12	1.30 ± 0.61	Large +
50KG CMJ peak power (w)	5455 ± 395	6987 ± 967	25 ± 9.0	1.87 ± 0.57	Large +
50KG CMJ relative power (w/kg^{-1})	61.6 ± 7.76	71.4 ± 8.36	16 ± 13	1.11 ± 0.85	Moderate +
Bench press 1RM (kg)	108 ± 21.2	127 ± 11.2	20 ± 9.6	1.14 ± 0.52	Moderate +
Weighted chin up 1RM (kg)	124 ± 16.3	142 ± 9.97	16 ± 6.6	1.33 ± 0.52	Large +
Multi Stage Fitness Test (m)	2164 ± 288	2563 ± 197	19 ± 6.9	1.55 ± 0.52	Large +

+ or – indicates an increase or decrease between provincial to international players, CL = Confidence limits, ES = Effect size

5.3.2 Forwards vs. backs

Anthropometrical and physical characteristics for international and provincial level rugby sevens forwards and backs can be found in Table 5.2. Rugby sevens forwards were taller (3.9%, ES = 1.29), heavier (11%, ES = 1.12), had greater CMJ power for both body weight (14%, ES = 0.50) and weighted jumps (14%, ES = 0.72), as well as weighted reverse grip chin up (7.9%, ES = 0.57). Backs were leaner (9.3%, ES = 0.42), and faster over 5 m (4.2%, ES = 0.75), 10 m (3.6%, ES = 0.92), and 40 m (2.5%, ES = 0.68). No clear differences were observed between the positional groups in age (3.4%), bodyweight CMJ relative power (1.9%), 50 kg CMJ relative power (2.7%), RSA (0.7%), horizontal jump (2.4%) and MSFT total distance (1.4%).

Table 5.2 Age and physical qualities of international and provincial rugby sevens forwards and backs

	Forwards (n = 28)	Backs (n = 37)			
	Mean ± SD	Mean ± SD	% Difference ± 95% CL	ES ± 95% CL	Qualitative outcome
Age	22.6 ± 3.38	21.9 ± 4.03	-3.4 ± 8.1	0.21 ± 0.49	Unclear
Height (cm)	187 ± 4.73	181 ± 4.92	-3.5 ± 1.4	1.29 ± 0.50	Large -
Mass (kg)	96.9 ± 8.03	87.7 ± 7.91	-11 ± 4.9	1.12 ± 0.50	Moderate -
Sum of skinfolds (mm)	70.9 ± 17.4	63.8 ± 9.78	-9.3 ± 14.1	0.42 ± 0.61	Small -
5m (s)	1.04 ± 0.07	1.00 ± 0.04	4.2 ± 3.6	0.75 ± 0.62	Moderate +
10m (s)	1.75 ± 0.08	1.69 ± 0.06	3.8 ± 2.2	0.92 ± 0.52	Moderate +
40m (s)	5.22 ± 0.22	5.09 ± 0.16	2.5 ± 2.0	0.68 ± 0.52	Moderate +
10 x 40m Average (s)	5.59 ± 0.22	5.55 ± 0.21	0.7 ± 2.7	0.17 ± 0.68	Unclear
Horizontal jump (cm)	2.54 ± 0.19	2.60 ± 0.16	-2.4 ± 3.9	-0.39 ± 0.65	Unclear
Bodyweight CMJ peak power (w)	7966 ± 1841	7113 ± 1624	-12 ± 16.1	0.50 ± 0.64	Small -
Bodyweight CMJ relative power (w/kg^{-1})	81.8 ± 17.3	79.6 ± 13.8	1.9 ± 13.5	0.10 ± 0.66	Unclear
50KG CMJ peak power (w)	7183 ± 1492	6242 ± 988	-14 ± 16	0.69 ± 0.73	Moderate -
50KG CMJ relative power (w/kg^{-1})	69.8 ± 10.5	67.6 ± 8.58	-2.7 ± 12	0.18 ± 0.78	Unclear
Bench press 1RM (kg)	119 ± 20	113 ± 20	-4.7 ± 11.7	0.24 ± 0.59	Unclear
Weighted reverse grip chin up 1RM (kg)	137 ± 15	127 ± 18	-7.9 ± 8.1	0.57 ± 0.57	Small +
Multi Stage Fitness Test (m)	2360 ± 337	2322 ± 289	-1.4 ± 6.9	0.10 ± 0.43	Unclear

+ or – indicates an increase or decrease between forwards to backs players, CL = Confidence limits, ES = Effect size

5.4 Discussion

The aim of this investigation was to compare the anthropometric and physical characteristics of international and provincial players as well as to compare forwards and backs. Substantial differences were found in all anthropometrical measures and performance tests between the two levels with international players being larger, leaner, faster, stronger, more powerful and with better maximal aerobic abilities. A secondary aim was to determine the magnitude at which differences exist between rugby sevens forwards and backs, where mostly small and moderate differences were observed between the two positional groups. The magnitude of differences in anthropometrical and physical characteristics between competition level are generally greater in the present study compared to rugby union [5]. Smart et al. [5] reported mostly trivial, small and moderate differences in anthropometrical and physical characteristics between international and provincial level rugby union players compared to mostly moderate and large differences in the present study

Similar to findings within rugby union [5, 6], international level players were taller, heavier and leaner than their provincial counterparts. The difference in age, with international players being ~3 years older on average, may possibly explain some of the differences in anthropometrical measures. Further, the international players are likely to receive increased nutrition and training support compared to provincial players. In comparison to previous anthropometrical data [29] from international rugby sevens players, the players in the present study were taller (~4 cm) and heavier (~7 kg), though players in the previously mentioned study were similar in age (21.9 ± 2.0 yrs) to the provincial level players in the present study, which may partially explain these differences.

The finding of greater speed in international players across all distances is in agreement with previous investigations comparing levels of competition in rugby union [5] and rugby league [27] International players in the present study were 3% (0.05 s, ES = 0.82) faster over 10 m and 2.4% (0.12 s, ES = 0.92) faster over 40 m than previously reported data for international rugby sevens players [29]. Interestingly, as the distance measured increased (5 m, 10 m, 40 m) so too did the magnitude of the difference in speed between international and provincial players. This finding suggests speed over longer distances may be of greater importance for international players than provincial level players. Mean sprint distance in domestic level rugby sevens matches has been shown to be ~18 m [25] however to date no study has reported the mean sprint distances of international players.

When comparing lower body power, international players produced more power than provincial players, both in bodyweight and weighted (Table 5.1). The magnitude of the effect was slightly lower when power at bodyweight and weighted CMJ were normalized to body mass between international and provincial players, however clear effects were still observed (ES = 1.11 – 1.30). The moderate difference in horizontal jump distance between the two groups suggest horizontal power, in addition to vertical power, is likely an important trait. The upper body strength of the international players in the present study is similar to data from semi-professional, professional and international rugby union backs in both bench press (125 kg and 127 kg, rugby union and rugby sevens, respectively) and chin up (131 kg and 142 kg, rugby union and rugby sevens, respectively) [34]. Collectively, these results suggest strength and power are important attributes for the rugby sevens player.

In addition to improving the ability to meet the high intensity running demands required in rugby sevens, a well-developed aerobic endurance may aid in reducing the magnitude of post-match fatigue, as an investigation in rugby league [103] reported players with better high-intensity running ability displayed a smaller decline in power output. Rugby sevens tournaments have been shown to induce neuromuscular fatigue both within and between tournaments played on consecutive weeks [92] and as such, improving this capacity would likely aid in maintaining physical performance throughout a competition. Total distance in the MSFT by international players in the present study was ~11% greater than data reported for professional rugby union backs [70] suggesting this quality may have greater importance in rugby sevens than rugby union.

In contrast to the mostly large differences in physical characteristics between international and provincial players, differences between forwards and backs were comparatively much smaller. Collectively, forwards were taller and heavier than backs, however differences were considerably less than comparisons between forwards and backs from rugby union [5]. Differences in positional roles are shown to be mostly small between rugby sevens backs and forwards [84, 85] however an increase in height is likely to be advantageous for forwards who contest a greater frequency of restart attempts and participate in lineouts, whilst an increase in mass is likely beneficial to forwards as they are required to engage in scrums and a greater frequency of tackles and rucks. The moderately faster sprint speeds across all distances by backs in the present study are likely explained by the greater requirement for backs to perform sprints (> 6 $m.s^{-1}$) during matches [84].

The lack of positional differences in MSFT and RSA suggest aerobic power and repeated sprint ability are important to both backs and forwards. Similarly, no differences were observed between the two groups in horizontal jump, relative power output in bodyweight and weighted CMJ, nor bench press strength, with only a small difference in chin up strength. It would appear then, that both power and strength are of similar importance to both forwards and backs. As a result of these findings, it would appear rugby sevens backs and forwards possess more similar than dissimilar physical characteristics.

5.5 Conclusion

From the findings of this study it would seem a wide variety of physical attributes distinguish rugby sevens players of different playing level. These findings also lend evidence to the contention that rugby sevens players are required to possess high levels of strength, power, speed and endurance. Whilst technical and tactical ability will also likely distinguish between provincial and international players, provincial rugby sevens players interested in progressing to the international level should place a strong focus on improving their physical capacities. Position-specific training programs for rugby sevens players are likely not required as in contrast to the other rugby codes, it appears forwards and backs are more similar than dissimilar in physical characteristics. In order to improve the specificity of strength and conditioning programs, future investigations should seek to identify the relationship between physical characteristics and individual match performance in rugby sevens.

5.6 Practical applications

Strength, power, speed, aerobic capacity and repeated sprint ability all differentiate between elite and semi-elite rugby sevens players and as such, lower level players should seek to increase all of these attributes if seeking to advance to higher levels of play. Specifically, lower level players should seek to attain increased maximal speed, repeated sprint ability, lower body peak power, upper body strength and maximum aerobic capacity. Given the similarity in physical demands and player characteristics between rugby sevens backs and forwards, position-specific programs are likely not required and coaches should instead focus on improving individual strengths and weaknesses. Physical and anthropometrical tests may be useful for rugby sevens coaches for team selection and talent identification.

Chapter 6

DEFENSIVE AND ATTACKING PERFORMANCE INDICATORS IN RUGBY SEVENS

Alex Ross, Nicholas Gill, John Cronin, Rita Malcata

6.0 Prelude

In the previous section, the match demands and physical characteristics of international and provincial rugby sevens players were established. The next chapters use the pertinent findings from these studies to further investigate performance in rugby sevens. This chapter utilizes event coding and novel statistical modelling to investigate the individual and team match actions related to attacking and defensive performance. Previous researchers have identified indicators related to performance in rugby sevens matches, such as time of possession, pass and tackle completion, and percentage of successful possessions. Whilst team performance indicators are valuable for performance analysis, it would seem of equal importance to also understand important individual match actions, as these would provide more specific criteria to rate match performance. Therefore, the purpose of this chapter was to determine the relationship between individual and team match actions and points scored and conceded during a match.

6.1 Introduction

Rugby sevens is an intermittent, contact sport played under nearly identical laws to fifteen-a-side rugby union (rugby union) though with fewer players (7 vs. 15, rugby sevens and rugby union, respectively) and for a shorter duration (14 vs. 80 minutes, rugby sevens and rugby union, respectively). Recent investigations of the match demands of rugby sevens has shown the physical [18, 25, 85] and technical [85] demands of rugby sevens are substantially different than rugby union, and as such the bevy of research related to rugby union may have little application to rugby sevens. This contention is most observable within the field of performance analysis, as while there have been an abundance of investigations of performance analysis in rugby union, inferences from these studies may not have application to rugby sevens.

Previous investigations of performance in rugby sevens has focused on temporal and notational differences between successful and unsuccessful teams [19, 24]. Hughes and Jones [24] compared the match statistics of successful (winning percentage >70%) and unsuccessful (winning percentage <70%) teams from the 2001 IRB Sevens World Series and reported successful teams had more clean line breaks (21%) and evasive runs (63%), formed fewer rucks (33%) and missed two fewer tackles per match. Though the authors analysed a relatively small number of matches (n = 16), these results provided some insight into identifying meaningful performance indicators in rugby sevens.

More recently, rugby sevens performance analysis research has progressed to identifying longitudinal differences in patterns of play on end of season standings [104], effect of performance indicators on tournament outcomes , and performance indicators related to points scoring and winning close matches [105]. In their recent investigation, Higham et al. [105] analysed IRB Sevens World Series games from 2008-2009 using mixed linear modelling and identified several indicators related to points scoring in rugby sevens. The authors reported ruck and maul retention and possession time having the strongest relationship with an increase in points scored, while conversely an increase in rucks and mauls formed and turnovers conceded were related to fewer points scored. Though the results of this study offer insight into factors related to points scoring, the performance indicators used were limited to general match statistics collected by the International Rugby Board, which may limit their effectiveness in informing practice, as it is likely more specific performance indicators would have a greater relationship with match outcomes. Further, there has been no investigation of the relationship between defensive performance indicators and points conceded in rugby sevens.

Understanding how specific match activities affect performance is useful in informing the technical and tactical preparation of teams, however, the use of simple match statistics may not have great utility [31]. For instance, investigations in rugby union have used classification scales for the quality of ball carries [33] and tackling [106] in order to further specify performance. There have been no investigations of specific performance indicators in rugby sevens. As such, the purpose of this study was to investigate the relationship between specific attacking and defensive performance indicators on points scoring and conceding, respectively, in international rugby sevens matches

6.2 Methods

Broadcast video of tournament matches from international rugby sevens matches were analysed using video analysis software (SportsCode v. 8.9, Sportstec, Australia). A total of 37 matches from the same 2013 IRB Sevens World Series tournament were used for the between team analysis, with 2-6 matches from 16 teams included. 50 matches, comprising of matches from all nine 2013-14 IRB Sevens World Series tournaments were used for the single team analysis. The current study conformed to the AUT University guidelines for observational research.

6.2.1 Video analysis

General match activities were first coded with performance indicators subsequently derived from these counts. The general match activities coded included; ball carries, tackles breaks, tackle evaded, line breaks, tries scored, positive and negative passes, positive and negative offloads, effective and ineffective attacking rucks, effective and ineffective defensive rucks, count of players involved in each ruck, turnover tackles, dominant tackles, effective tackles, passive tackles, tackles in which an offload was made, and missed tackles.

Two experienced rugby sevens analysts coded all matches. Intra-rater reliability was assessed through coding the same two matches, four weeks apart. Inter-rater reliability was assessed by both analysts coding the same two matches. The intra-rater intraclass correlation coefficient (ICC) and typical error of measurement (TEM) for coding the match activities was < 6% and greater than 0.87 respectively, for intra-rater reliability while inter-rater TEM was < 8% and ICC > 0.80.

6.2.2 Performance indicators

Operational definitions of the performance indicators analysed are shown in Table 6.1. Performance indicators were developed based on; a) the opinion of a rugby sevens analyst with seven years of experience in international rugby sevens; and, b) the results of previous investigations within rugby sevens and rugby union [12, 13, 32]. Indicators related to set-piece (scrums, lineouts, penalties and restarts) were purposely omitted as these have previously received attention in rugby sevens analysis [104]. Further, indicators were developed on the basis of their utility in informing team practice and in rating individual player performance. A total of thirteen performance indicators were developed; six related to defensive performance and seven related to attacking performance.

6.2.3 Statistical analysis

In order to investigate the effect of performance indicators on points scored and conceded, a statistical method previously used within performance analysis of international rugby sevens [105] was adopted. For the multiple team analysis, means and within and between team standard deviations of performance indicators were derived through mixed-model analysis with a random effect for team. The intercept of the model was used as an estimate of mean values of performance indicators while the within-team standard deviation was calculated as the residual variance and the between-team standard deviation calculated from the random effect. For the single team analysis, estimated means and standard deviations for each of the performance indicators were calculated for the team.

Separate analyses were conducted for the effect of performance indicators related to points scored and points conceded. For each analysis, a mixed model was used with a fixed effect for performance indicator and a random effect for team. The effect of a change in each performance indicator within-teams on either points scored or points conceded was analysed by multiplying the slope of the relationship by two within-team standard deviations [83]. Similarly, the effect of a change in each performance indicator between-teams was assessed by multiplying the slope of the relationship by two between-team standard deviations. For all analyses, ± 1 point was defined as the smallest meaningful change in points conceded and scored [104, 105, 107].

Table 6.1 Operational definitions for attacking and defensive performance indicators

Defensive indicators	
Tackle score	Average tackle points awarded per tackle attempted (total points/tackle attempts); Tackle points are awarded on the following scale: turnover tackle = 3 points, dominant tackle = 2 points, effective tackle = 1 points passive tackle = 0 points
Dominant tackles	Sum of turnover and dominant tackles affected
Ineffective tackles	Sum of passive tackles and offloads allowed
Missed tackles	Sum of tackles attempted and missed
Defensive ruck score	Average effectiveness points awarded per defensive ruck contested; Effectiveness points are awarded on the following scale: Effective defensive rucks: 1 player committed = 3 points, 2 players = 2 points, 3 players = 1 points, Ineffective defensive rucks: 1 player committed = -1 points, 2 players = -2 point, 3 players = -3 point
Defensive ruck average	Average count of players contesting defensive rucks per defensive ruck contested
Attacking indicators	
Tackles evaded	Count of tackles evaded by the ball carrier
Line breaks	Count of times the attacking team breaks the defensive line
Attacking ruck score	Average effectiveness points awarded per attacking ruck formed; Ruck points are awarded on the following scale: Effective attacking rucks: 1 player committed = 3 points, 2 players = 2 points, 3 players = 1 points, Ineffective attacking rucks: 1 player committed = -1 points, 2 players = -2 points, 3 players = -3 points
Attacking ruck average	Average count of players committed to attacking rucks per attacking ruck formed
Passes: rucks	Ratio of passes completed to attacking rucks formed
Offload score	Count of balls successfully released in the tackle minus unsuccessful attempts
Handling errors	The sum of knock-ons, poor passes, and dropped balls by the player

Given the previously identified large variability in the frequency of statistics between matches [85, 104, 105, 107]a change in two standard deviations may not provide useful information for coaches. In order to provide information that may have a greater practical utility for coaches and support teams, a practical difference was developed for each performance indicator (See Table 6.2) and multiplied by the slope of the relationship between the respective performance indicator and either points conceded or points scored.

Table 6.2 Per-match practical differences in performance indicators

Defensive indicators	Practical Difference
Tackle score	Out of ten total tackles, a change of two ineffective to dominant
Defensive ruck score	Out of ten total defensive rucks, a change of two rucks from ineffective to effective
Dominant tackles	An increase in two dominant tackles per match
Defensive ruck average	Out of ten total defensive rucks, a decrease of three players committed
Ineffective tackles	A decrease of two ineffective tackles
Missed tackles	A decrease of one missed tackle
Attacking indicators	
Line breaks	An increase of two line breaks
Defenders beaten	An increase of two defenders beaten
Ruck score	Out of ten total rucks, a change of two rucks from ineffective to effective
Passes: rucks	An increase of one pass per ruck formed
Offload score	Out of five total offloads, a change of two from ineffective to effective
Handling errors	A decrease of one less handling error
Ruck average	Out of ten total rucks, a decrease of three players committed

6.3 Results

Means and the observed, between-team, and within-teams standard deviations for performance indicators across all teams from an international rugby sevens tournament are provided in Table 6.3. In agreement with previous research, typical match-match variability for all performance indicators was greater within-teams than between-teams, with the exception of passes to rucks. Offload score had the highest variability match to match (coefficient of variation = 298%).

Descriptive statistics for performance indicator values from a single team across nine tournaments are presented in Table 6.4. Teams scored 18.5 points per match, had 2.60 line breaks, and affected 8.08 ineffective tackles.

Table 6.3 Rugby sevens performance indicators per match during an international rugby sevens tournament (n = 74 observations, 16 teams)

	Mean	Observed SD	Within-team SD	Between-team SD
Defensive indicators				
Tackle score	1.86	0.61	0.50	0.35
Defensive ruck score	3.30	0.95	0.86	0.40
Dominant tackles	2.08	2.33	2.21	0.74
Defensive ruck average	1.22	0.27	0.26	0.07
Ineffective tackles	8.08	3.94	3.65	1.48
Missed tackles	5.16	3.41	3.2	1.17
Attacking indicators				
Points Scored	18.5	13.3	11.6	6.6
Line breaks	2.60	1.99	1.68	1.05
Defenders beaten	6.29	4.11	3.42	2.28
Ruck score	3.48	0.86	0.83	0.22
Passes: rucks	3.00	2.12	0.94	1.91
Offload score	0.98	2.93	2.89	0.49
Handling errors	2.31	1.76	1.68	0.53
Ruck average	1.19	0.21	0.19	0.1

Table 6.4 Rugby sevens performance indicators per match from one team across an international season (n = 50 observations)

	Mean	Observed SD	Within-team SD	Between-team SD
Defensive indicators				
Points Scored	28.8	12.7	8.5	9.5
Tackle score	2.35	0.48	0.44	0.18
Defensive ruck score	1.06	1.08	1.05	0.26
Dominant tackles	3.44	2.09	2.02	0.51
Defensive ruck average	1.36	0.19	0.19	0.01
Ineffective tackles	7.02	3.81	3.64	1.12
Missed tackles	2.77	2.58	2.58	0.01
Attacking indicators				
Points Scored	28.8	12.7	8.5	9.5
Line breaks	3.73	1.95	1.22	1.52
Defenders beaten	8.42	4.2	3.09	2.84
Ruck score	3.48	0.86	0.83	0.22
Passes: rucks	3.24	1.52	1.46	0.42
Offload score	1.86	2.81	2.64	0.97
Handling errors	2.33	1.78	1.65	0.67
Ruck average	1.11	0.14	0.13	0.06

Substantial, clear effects were identified for all 13 performance indicators in the multiple team analysis. Of the six defensive performance indicators, tackle score had the largest effect on points conceded, with a two between-team SD increase equating to a decrease in 12.3 points (90% confidence limits (CL), ± 1.8) conceded per match.

Similar to the multiple team analysis, all performance indicators from the single team were substantial and clear. The relationships between performance indicators and points conceded and scored largely mirrored the results of the multiple team analysis, though magnitudes were generally smaller (Figure 6.2). Twelve of the 13 performance indicators showed substantial relationships with points scored and conceded when the effect of a practical change was analysed, with only offload score resulting in a trivial outcome.

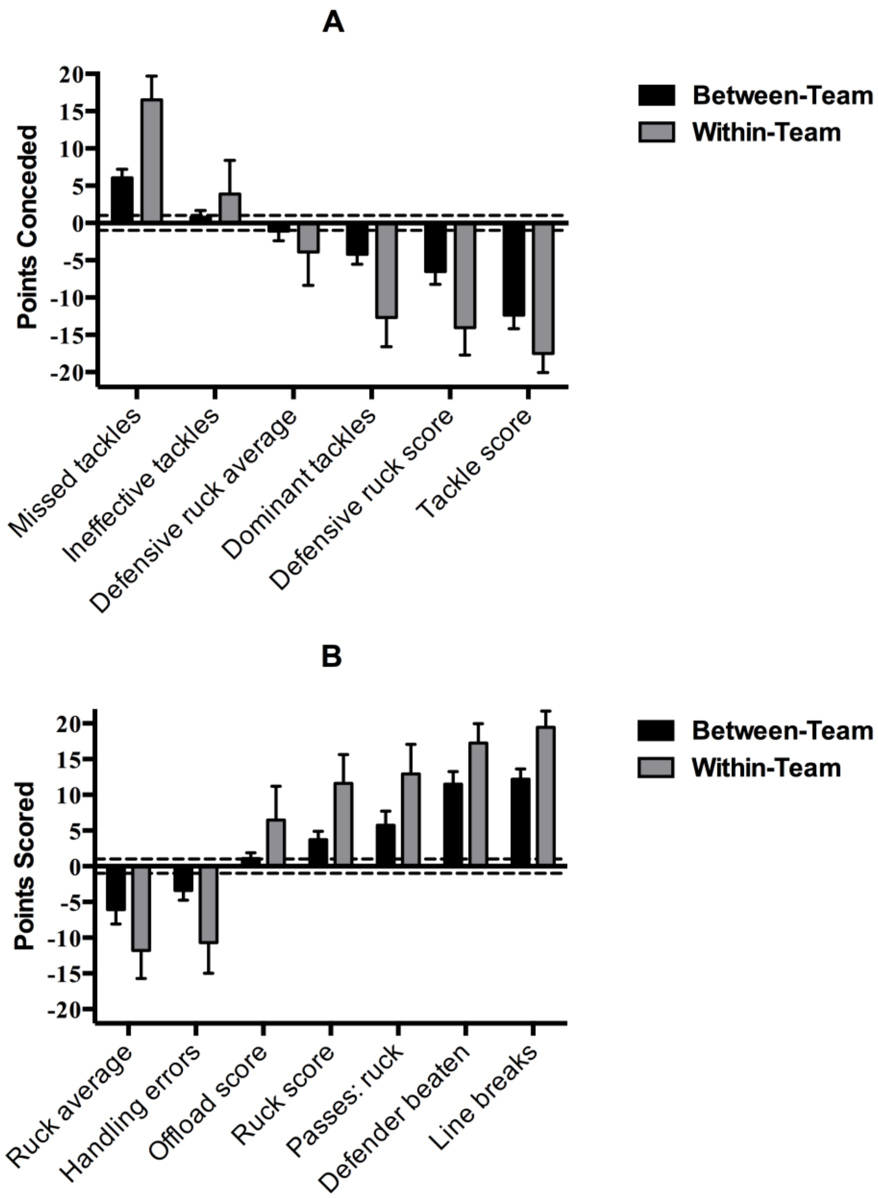

Figure 6.1 Effect of an increase in two between-team and within-team standard deviations on (A) points conceded and (B) points scored in international rugby sevens matches. Error bars represent 90% confidence limits. Shaded area represents the smallest meaningful effect (± 1 point)

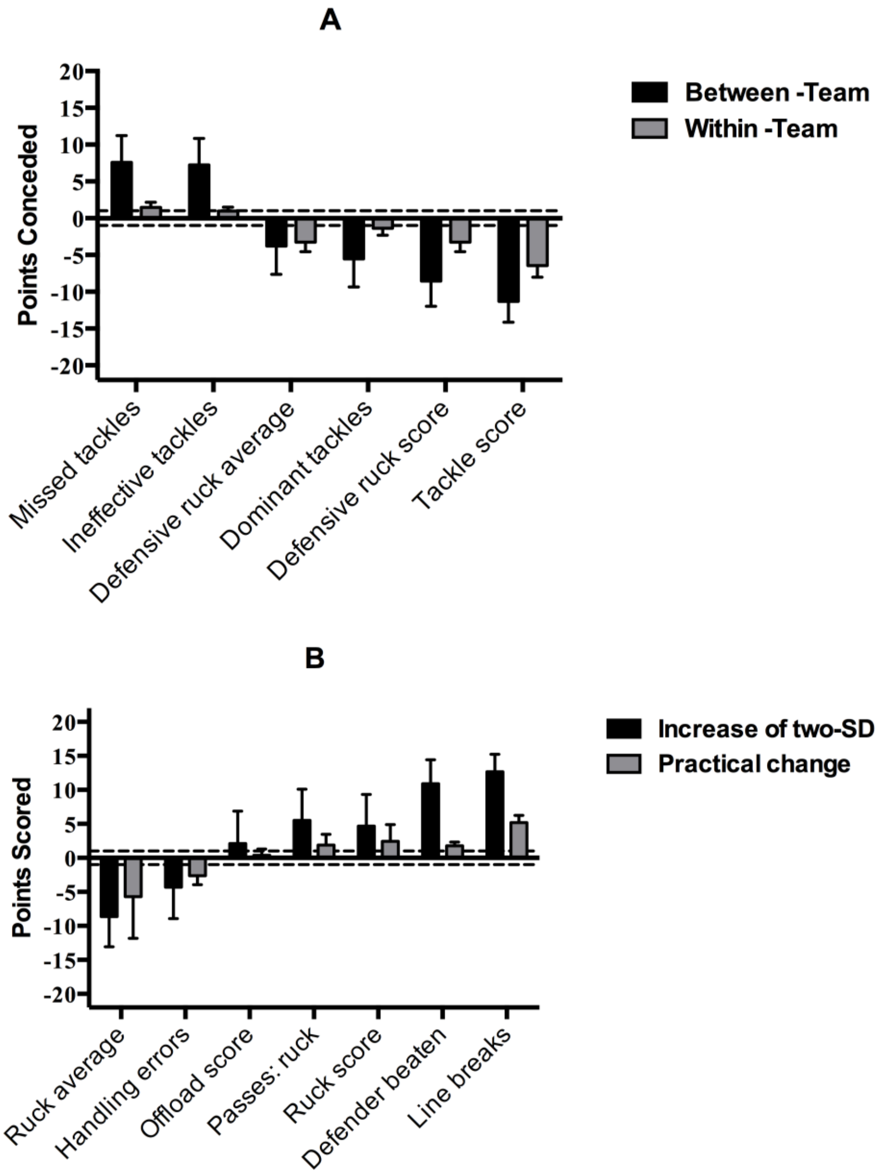

Figure 6.2 Effect of an increase in two observed standard deviations and a practical change on (A) points conceded and (B) points scored by a single international rugby sevens team. Error bars represent 90% confidence limits. Shaded area represents the smallest meaningful effect (± 1 point)

6.4 Discussion

The purpose of this study was to investigate the influence between selected performance indicators and points scored and conceded in international rugby sevens matches. All 13 performance indicators analysed showed substantial relationships with points scored and conceded both across an entire tournament as well as within a single team across an IRB Sevens World Series season (9 tournaments). Increasing the effectiveness of tackles reduced the number of points conceded while increasing the number of defensive line breaks resulted in more points being scored. The results of this study may provide analysts and coaches with performance indicators to track the performance of teams and individual players.

To decrease the number of points conceded, rugby sevens teams should seek to improve the effectiveness of their tackles. A change in two tackles from ineffective to effective out of a total of ten tackles equated to a decrease in ~6 points conceded per match. Whilst the results of previous investigations in rugby sevens [19, 24] reported similar tackle completion rates for successful (86%) and unsuccessful (83%) teams, the results of the present study suggest the effectiveness of the completed tackle may be more meaningful than tracking whether a tackle was simply completed or not. The decrease in points conceded associated with an increase in dominant tackles can likely be explained by these tackles providing the defensive team an opportunity to turn the ball over at the breakdown and create an attacking opportunity. Conversely, an ineffective tackle may allow the attacking team to continue to play the ball through off loading or moving the ball away quickly from the ruck.

Contesting the oppositions ruck after a tackle has been completed appears to be an effective tactic, as defensive ruck score had the second strongest relationship with the number of points conceded. By effectively contesting an opposition ruck, the attacking team may be required to commit more players to the ruck in order to play the ball, thus leaving fewer attacking players ‘on their feet’. Similarly, an effective contest may allow the defending team time to organize before the ball is played. It appears that contesting the opposition breakdown with a greater number of players is an effective tactic, as an increase in the average number of players committed to a defensive ruck was related to a decrease in points conceded (~3 points per match). However, contesting with a greater number of players may be a risky tactic, as the number of points conceded by a two SD increase in ineffective rucks was greater for rucks contested by two players (6.7) than those contested by one player (3.9).

Rugby sevens should make a concerted effort to create line break opportunities, as an increase in ~2 line breaks per match equates to an increase of ~12 points per match. Given this association, it appears a high likelihood that if an attacking player breaks the defensive line, a try will be scored. Line breaks have been identified as key to try scoring in rugby union [16, 24], and this effect is likely amplified in rugby sevens in which there are fewer defenders to make a tackle behind the defensive line once a player has broken free. Whilst the creation of line breaks can likely be explained by a multitude of both technical, tactical and physical factors, it seems logical that the ability to evade tackles would result in a greater number of line break opportunities. Indeed, the present study identified a strong relationship between an increase in defenders beaten and the number of points scored, whilst a previous investigation in rugby union identified a relationship between sprint speed and the ability to break the line [34]. Similarly, an increase in the number of missed tackles was associated with an increase in points scored. Rugby sevens coaches should consider selecting players that possess an ability to evade tackles, or to adopt training practices aimed at improving this ability.

In order to score more points, teams should seek to both reduce the number of players they commit to attacking rucks and to be more effective with the players they have committed. An increase in the average number of players committed to attacking rucks was associated with a decrease in points scored, while conversely allowing the ball to be quickly recycled with fewer players committed was associated with a substantial increase in points scored. An effective ruck with fewer players committed allows the ball to be played to a greater number of attacking players, which may result in the creation of overlaps. Conversely, committing a greater number of players to win the ball leaves fewer players available to attack.

Previous research [105, 107] attributed both the number of rucks and mauls formed and passes completed per minute of possession with a decrease in point scoring. In contrast, other researchers [107] have reported that teams with a higher end of season ranking had a greater number of passes and rucks per match. In the present study, teams whom had a greater ratio of passes completed to rucks formed tended to score more points. Avoiding tackle situations by completing more passes may cause the defence to become fatigued. This finding is in agreement with analysis of international rugby sevens matches from 2001 [24] in which the authors concluded effective teams adopted a 'cat and mouse' style of play. Similarly, successfully freeing the ball during a tackle contest allows the attacking team to continue rather than forming a ruck. An increased offload score (successful offloads – unsuccessful offloads) showed a clear relationship with an increase in points scored, however as an increase in handling errors was associated with a decrease in points, teams should aim to attempt offloads when the chance of success is high.

Analysis of a single team over the course of the season yielded similar results to the multi-team analysis, though the magnitude of the effect was generally smaller for each performance indicator. These results suggest the performance indicators included in the present study may be of use when tracking the performance of a team over the course of one or more seasons. Though the magnitude of each effect decreased when analysing derived 'practical changes', these results may have more practical utility for coaches and support staff due to their simpler interpretation. The practical changes also reduce the effect of the large match-to-match variability of teams in which a two SD change may be unrealistic.

It should be noted that the current study was limited to a single tournament when analysed multiple teams, as well as a single team when analysing multiple tournaments. As such, caution should be used in the interpretation of the outcomes. Whilst the performance indicators in the present study are likely heavily influenced by team tactics and technical skill, many of the indicators are also likely influenced by the physical characteristics of the players. Future research should seek to investigate the effect of physical characteristics on individual match performance.

6.5 Conclusion

The analysis of the relationship between performance indicators and points scored and conceded identified 13 indicators that are useful in profiling team and individual player performance. The clear results from the analysis of a single team over the course of an IRB Sevens World Series season showcase the utility of the performance indicators in tracking longitudinal performance. To concede fewer points, teams should seek to improve the effectiveness of tackle attempts and slow down the opposition's ability to play the ball during defensive ruck contests. To score more points, teams should focus on creating more line break opportunities by evading more tackles, committing fewer players to attacking rucks, and causing the defence to tire by avoiding tackle contests.

Chapter 7

THE RELATIONSHIP BETWEEN PHYSICAL CHARACTERISTICS AND MATCH PERFORMANCE IN RUGBY SEVENS

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7.0 Prelude

The specificity of athlete physical preparation programs should reflect the relative importance of each physical trait to competition performance. In order to develop targeted training programs, it is important that the relationship between physical characteristics and on-field performance is understood. With this knowledge, coaches can design training programs aimed at not only improving a physical trait but specifically targeting physical traits related to match performance. Chapter 6 established the individual match actions related to performance, while Chapter 5 identified physical characteristics that distinguish between international and provincial players, however the link between physical characteristics and match performance remains unclear. Therefore the purpose of this chapter was firstly to investigate the relationship between physical characteristics and individual match performance indicators and secondly to identify the affect of a change in a physical characteristic on match performance in international and provincial rugby sevens players.

7.1 Introduction

Rugby sevens is a high intensity, intermittent, collision field sport played internationally [108]. Rugby sevens involves similar rules and actions to 15-a-side rugby union (rugby union) and is played on the same field dimensions; however, rugby sevens is played with only seven players (as opposed to 15) while matches are 14 minutes in duration (as opposed to 80 min). Previous investigations of the match demands of rugby sevens and rugby union have shown substantial differences exist in the movement patterns and match activity profiles of players [1, 84, 85]. Further, in contrast to rugby union in which the match demands vary greatly by position, the positional demands of backs and forwards in rugby sevens are relatively similar with both groups performing similar movement and technical demands [84, 85]

There has been limited research on the physical measures of rugby sevens players, with only two studies to date [29, 109]. Higham et al. [29] reported anthropometric, speed, repeated speed, and aerobic endurance characteristics of international rugby sevens players, reporting similar profiles (Coefficient of variation (CV) 2.5-22%) for most measures across a team. Ross, Gill and Cronin [109] compared the anthropometrical and physical characteristics of international and provincial rugby sevens players, reporting international players were substantially taller, heavier, faster, had greater upper body strength and lower body power, and performed better during maximal aerobic testing (Effect size 0.26 – 2.26) with mostly trivial and small differences between backs and forwards. Whilst it would appear plausible that there is a link between physical characteristics and match performance in rugby sevens, no investigations exist supporting this contention.

Notational analysis of rugby sevens matches has been used to identify both the match demands as well as factors related to success [20, 104]. Specifically, recent investigations in rugby sevens have identified factors related to points scoring and international ranking [104]. Whilst these investigations have only reported match data for entire teams, many of the factors reported are sum values of individual actions (e.g. defenders beaten, line breaks, offloads) and as such it can be assumed these actions would also be indicative of individual performance. However, how these match performance indicators relate to physical characteristics is presently unknown.

Investigators within rugby league [54, 110], Australian rules football [49, 53], and rugby union [34] have reported the relationships between physical measures and match performance. Specific to rugby union, Smart et al. [34] reported moderate correlations ($r > 0.3$) between 10 m and 20 m speed and the number of tackles evaded and line breaks in professional rugby union players, while performance in a repeated sprint test was related to a players work rate ($r = -0.38$). The results of these investigations inform player profiling and the development of targeted physical preparation programs. Given the lack of a similar investigation specific to rugby sevens, the purpose of this investigation was to identify relationships between physical measures and factors related to match performance in provincial and international rugby sevens players.

7.2 Methods

A total of 40 international (n = 18) and provincial (n = 22) rugby sevens players participated in the present study. All international players were from the same team while provincial level participants comprised of players from four provincial rugby sevens teams. All participants were free from injury and provided written informed consent to participate in the study. The AUT Ethics Committee provided ethical approval.

7.2.1 Physical measures

7.2.1.1 Speed

Players performed two sprints over 40 m on an indoor, track surface. Prior to performing the sprint, players performed a 15 minute warm up consisting of five minutes of light jogging, five minutes of dynamic stretches for the lower limbs, and finishing with three sprints over 40 m at 70%, 80%, and 90% intensity. Dual-beam electronic timing gates (Speedlight TT, Swift Performance Equipment, Lismore, Australia) were placed at 0 m, 5 m, 10 m and 40 m distances. Players commenced sprints 0.3 m behind the starting gate from a crouched, split standing start with no countermovement. Speed at each split was recorded to the nearest 0.01 s. Participants performed two sprints with five minutes of passive rest interspersed between efforts. Each participant's fastest sprint was used for analysis. Sprint momentum (bodyweight [kg] * sprint velocity $m.s^{-1}$) was calculated as the average velocity from each players 10 m sprint time, with velocity calculated from the following formula: (10 m (s)/10) and expressed in arbitrary units. The coefficient of variation for sprint times under similar protocols has been shown to be 1.9 – 2.0% [96].

7.2.2.2 Power

Players performed maximal bodyweight and weighted countermovement jumps (CMJ) whilst holding a one-kilogram (kg) pole for the bodyweight condition and a 50 kg barbell for the loaded condition. A linear position transducer (Gymaware, Kinetic Performance, Australia) was affixed to the pole or bar and used to measure peak concentric power. Briefly, the Gymaware measures displacement-time data to calculate velocity, force and power using methods described previously [23]. Players were asked to lower to a self-selected depth and rapidly jump as high as possible. Players were given two trials of three jumps under each condition with three minutes passive rest between trials, with the highest value recorded by each player included in analysis. The coefficient of variation for weighted jumps squat peak power using similar methods has been shown to be 2.3% for weighted jumps [97] and 5.3% for bodyweight jumps (Turnbull et al. 2013).

A maximal horizontal jump (HJ) was used to measure horizontal lower body power. Players performed three practice jumps after which three maximal countermovement horizontal jumps with two minutes rest between trials were recorded for analysis. Jump distance was measured from toe off to the back of the hindmost foot to the nearest cm. Participants were required to "stick" the landing in order for the jump to be included in analysis. The coefficient of variation for the countermovement horizontal jump has been shown to be 2.4% [98].

7.2.2.3 Repeat Sprint Ability (RSA)

A 10 x 40 m sprint test was used to assess RSA. Players ran back and forth between the timing lights on an indoor track surface, departing each sprint every 30 s. Average (mean) sprint time across the ten sprints were measured to the nearest 0.01 s. A similar repeat sprint assessment reported a coefficient of variation of 1.9% [99].

7.2.2.4 Upper-Body Strength

Bench press and reverse chin up 2-5 repetition maximum (RM) assessments was used to assess upper body strength. For the bench press, players chose a self-selected grip width and were required to lower the bar to chest level with feet required to remain in contact with the floor at all times. Players began the chin up with an underhand grip, with arms extended and were required to raise themselves to where their chin was over the bar, with the total load used including bodyweight used in analysis. One repetition maximum (1RM) from the lifts was calculated from the following formula: 1RM = (100xweight)/(101.3 – (2.67123xreps)) [100], with the coefficient of variation for the bench press and chin up shown to be 1.5% and 2.6%, respectively [96].

7.2.2.5 Maximal Aerobic Capacity

To assess maximal aerobic capacity, the 20 m multistage fitness test (MSFT) was used [101]. This test was chosen due to the preference of the international team coach. Players were required to run back and forth along a 20 m indoor track in time with progressively faster ‘beeps’ emitted from a stereo. Players were required to stay in time with the beeps and the test finished when a player was no longer able to perform a shuttle in the required time. The final shuttle reached was converted to total distance covered (m) by each player for analysis. The test-retest reliability for the MSFT has been shown to be 3.5% [96].

Table 7.1 Operational definitions of match statistics used in analysis

Match statistic	**Definition**
Defenders beaten	Count of tackles evaded by the ball carrier
Line breaks	Count of times the ball carrier breaks the defensive line
Tries scored	Count of tries scored by the player
Effective attacking ruck	Count of attacking rucks in which the player successfully clears the opposition making the ball available to play
Effective defensive ruck	Count of times an attacking ruck is successfully disrupted by the player
Tackle score	The sum of tackle points awarded to the player divided by the total tackles attempted
Dominant tackles	The count of dominant and turnover tackles affected by the player
Missed tackles	The count of tackles attempted and missed by the player
Work rate	The sum of tackles affected, effective attacking rucks, and effective defensive rucks
Handling errors	The sum of knock-ons, passes to ground, and dropped balls by the player

7.2.3 Match activities

All match activities were coded by one experienced analyst using video analysis software (SportsCode v.8.9, Sportstec, Australia). The match activities chosen for analysis in this study have been reported to be relevant to rugby sevens [105, 111]. Operational definitions of the match activities are detailed in Table 7.1. Intra-rater reliability for the analysis was assessed by coding the same four matches four weeks apart with the TEM for match activities < 8%. To limit the effect of abnormally high values, data was only included for players who contested a minimum of 50 cumulative minutes of match time.

7.2.4 Statistical analysis

Between-player means and standard deviations were determined for all physical measures and match activities. To account for differing playing times between players as well as differences in duration between matches, match activity values were summed for each player and normalized to a per-14 minute average using the following equation: (reported value = 14*observed value/minutes played) [34]. Pearson correlations between physical measures and match statistics were calculated. The magnitude of correlations was assessed using the following scale: <0.1 = trivial, 0.1-0.3 = small, 0.3 – 0.5 = moderate, and 0.5 – 0.7 = large [82]. An inference about the true (large-sample) value of the correlation between measures was based on uncertainty in its magnitude: if the 90% confidence interval (CI) overlapped small and negative values, correlation was deemed unclear [90].

The relationships between physical measures and match activities that displayed moderate and large correlations were further analysed. For each pair of physical characteristic and match activity a generalized linear mixed model was used to calculate changes in match activity (the dependent variable) as the result of a change in a physical characteristic (the fixed effect). Match activities were assumed to have a Poisson distribution and physical characteristic values, with the exception of measures of speed, were log-transformed. Changes in match activity were calculated as factor difference, and then back-transformed to view changes as a percent. To assess the effect of a change in a physical measure on subsequent match activity performance, the slope of the relationship between the physical measure and match activity was multiplied by two standard deviations of the physical measure. Two standard deviations represents the difference from a poor performance (mean - 1 SD) to a high performance (mean + 1 SD) [90]. Uncertainty of estimates was expressed as 90% confidence intervals, with changes in match activity deemed unclear if the CI crossed the threshold for positive and negative effects. Analyses were performed with the Statistical Analysis System (version 9.4, SAS institute, Cary, NC).

7.3 Results

Means and standard deviations for per-14 minute match activity values and physical measures of international and provincial rugby sevens players can be found in Table 7.2. The average total match time per player was 83.6 minutes (5.97 full matches).

Table 7.2 Between player means ± standard deviations of match statistics and physical characteristics for international and provincial rugby sevens players (n = 40)

Match statistic	Mean ± SD
Defenders beaten	1.34 ± 0.93
Line breaks	0.49 ± 0.50
Tries scored	0.54 ± 0.41
Effective attacking ruck	1.18 ± 0.73
Effective defensive ruck	0.50 ± 0.54
Tackle score	0.96 ± 2.38
Dominant tackles	0.33 ± 0.36
Missed tackles	0.41 ± 0.36
Work rate	3.21 ± 1.49
Handling errors	0.31 ± 0.32
Physical characteristic	
5 m (s)	1.00 ± 0.05
10 m (s)	1.70 ± 0.08
40 m (s)	5.11 ± 0.20
10 m momentum (au)	552 ± 47
10 x 40 m average (s)	5.51 ± 0.20
Horizontal jump (cm)	264 ± 13.3
Bodyweight CMJ peak power (w)	7976 ± 1827
50KG CMJ peak power (w)	6596 ± 1127
Bench press 1RM (kg)	122 ± 14
Weighted reverse grip chin up 1RM (kg)	136 ± 12
Multi Stage Fitness Test (m)	2418 ± 287

au = arbitrary units; CMJ = Counter movement jump

Correlation coefficients between selected physical measures and performance can be found in Table 7.3. Clear, substantial relationships were identified between numerous pairs of match activities and physical measures. Large correlations (~ - 0.50) were identified between 40 m performance and defenders beaten and line breaks. Performance in the 10 x 40 m exhibited a large correlation with tackle score and moderate correlations with tries scored effective defensive rucks, dominant tackles, missed tackles, work rate, and handling errors. Horizontal jump had a large correlation with tackle score and a moderate correlation with defenders beaten. Small correlations were observed for bench press strength and defenders beaten and effective attacking and defensive rucks, while chin up strength had moderate correlations with effective defensive rucks and tackle score.

Mixed-model analysis of the effect of a change in physical measure on match activity values revealed clear, substantial effects for 11 pairs of physical measures and match activities (see Figure 7.1). An increase in line breaks per match was associated with a two standard deviation change in 10 m (74%, 90% CI 27-91%) and 40 m (56%, 90% CI 20-76%) sprint time, while the number of defenders beaten was also increased by an improvement in 10 m (50%, 90% CI 12-72%) and 40 m (60%, 90% CI 26-78%) sprint time as well as an improvement in horizontal jump performance (78%, 90% CI 12-184%).

7.4 Discussion

This is the first study to investigate the relationship between physical measures and match performance in rugby sevens players. This is also the first study to provide normative individual match activity values. Correlation coefficients identified numerous moderate and large relationships between selected physical measures and match activities. The results of this investigation suggest individual physical measures may impact on-field performance in rugby sevens.

Measures of speed showed moderate and large relationships with many attack-specific match activities. The large relationships between 40 m sprint time and the number of line breaks and defenders beaten per match suggest maximal speed is likely to be important in rugby sevens. However, the similar results for the 10 m sprint time suggest acceleration is also likely to be important as well. Interestingly, despite strong relationships with 10 m (r = 0.87) and 40 m (r = 0.70), the relationships between 5 m sprint performance and line breaks and defenders beaten were smaller. The association between measures of speed and line breaks and defenders beaten is in agreement with a previous investigation in rugby union [34].

Defensive and contact-specific match activities also showed relationships with speed, as all three sprint distances (5 m, 10 m, 40 m) showed moderate relationships with tackle score (r = -0.32 – 0.38) while 10 m and 40 m sprint time were moderately related with the number of missed tackles (r = 0.43 and 0.47, 10 m and 40 m, respectively). Given the increased relative area for players to run in rugby sevens, it would appear sprint speed is an important factor in tackle performance. Sprint momentum at 10 m appeared to be a greater indicator of performance than 10 m sprint time alone in contact situations, as evidenced by the stronger relationships between 10 m sprint momentum and effective defensive rucks (r = 0.36 and -0.09, respectively) and dominant tackles (0.31 and -0.14, respectively). An investigation in rugby league [112] also identified sprint momentum as a better indicator of performance in contact scenarios than sprint velocity.

Table 7.3 Correlation coefficients between physical measures and match activities for international and provincial rugby sevens players

	Defenders beaten	Line breaks	Tries scored	Effective attacking ruck	Effective defensive ruck	Tackle score	Dominant tackles	Missed tackles	Work rate	Handling errors
5 m	- 0.27	- 0.35*	-0.17	0.11	- 0.22	- 0.38*	-0.22	0.22		
10 m	- 0.41*	- 0.47*	- 0.27	0.16	- 0.09	- 0.32*	-0.14	0.43*		
40 m	- 0.50**	- 0.51**	- 0.25			- 0.36*	-0.20	0.47*		
10 m momentum	0.30*	0.32*	0.37*	0.22	0.36*	0.41*	0.31*	-0.37*		
10 x 40 m			- 0.31*	- 0.04	- 0.33*	- 0.59**	- 0.41*	0.32*	- 0.39*	0.48*
Horizontal jump	0.47*			- 0.16	0.24	0.50**	0.39*	- 0.24		
Bodyweight CMJ	0.11			0.56**	0.48*	0.12	0.13	- 0.31*		
50KG CMJ	0.06			0.34*	0.42*	0.42*	0.47*	- 0.42*		
Bench press 1RM	0.16			0.25	0.16					
Chin up 1RM				0.27	0.30*	0.36*	0.27	- 0.27		
MSFT				0.38*	0.34*	0.11		- 0.22	0.36*	-0.15

Data shown are Pearson correlations, 90% confidence limits ± ≤ 0.32; *Denotes a moderate correlation; **Denotes a large correlation

It appeared both vertical and horizontal jump tests have utility in the assessment of rugby sevens players, as performance in horizontal and vertical jumps (bodyweight and weighted) exhibited moderate and large correlations with match performance indicators. Players who possessed greater horizontal jump distance evaded more tackles, made a greater number of dominant tackles, and had a higher tackle score while players who possessed greater peak power in bodyweight and weighted counter movement vertical jumps were more effective in both attacking and defensive rucks (r = 0.34 – 0.59). Previous research [54] in rugby league identified a strong (r = 0.42) relationship between vertical jump performance and the ability to evade tacklers, however it appears that the horizontal jump is a more useful indicator in rugby sevens given the substantially greater relationship (r = 0.50 and 0.06, horizontal and bodyweight vertical, respectively) with the number of defenders beaten. Given the differences in relationships with match activities between the three jump measures, it would seem of importance to include horizontal, vertical and weighted vertical jump measures when assessing rugby sevens players.

The finding of mostly trivial and small correlations between upper body strength (bench press and weighted reverse grip chin up) and match activities is similar to findings in rugby union [34]. As evidenced by the moderate correlations between chin up strength and effective defensive rucks (r = 0.30) and tackle score (r = 0.36), upper body pulling strength is an important attribute in contact situations. It is possible other measures of strength, such as lower body specific measures or upper body pulling strength, may possess stronger relationships with match performance than the measures included in the present study. It is also possible upper body power may be better related to performance than upper body strength, as it has been shown in rugby union that power is a greater indicator of playing level than strength [6], however no measures of upper body power were assessed in the present study. As such, further research is required to investigate the relationship between strength and power in the upper body and match performance in rugby sevens.

Rugby sevens is a high intensity sport that requires players to repeatedly sprint, change direction, and contest tackles and rucks, interspersed with periods of low and moderate intensity running [79, 84, 85]. High levels of both aerobic power and repeated sprint performance were both moderately related (r = 0.36-0.39) to a greater rate of activities performed during a match. The strong relationship (r = -0.59) between tackle score and 10 x 40 m performance suggests the ability to maintain speed under fatigue is important to consistently affect positive tackles. Repeated sprint performance also appears related to the ability to maintain skill execution under fatigue, as players with poor repeated sprint performance commit a greater frequency of handling errors, though interestingly only a small relationship was identified between the MSFT and handling errors. As rugby sevens is most often played in a tournament style over multiple days, future research should seek to investigate the relationship between repeated sprint and aerobic power performance and the ability to maintain performance over the course of a tournament.

A novel aspect of the present study was the use of a mixed model to identify the effect of a change in a physical measure on match activity performance. In addition to assessing the effect of a two between-player SD change in performance, representing the difference of moving from a typically low to typically high performance, this model also allows for investigating a real-world, practical change in each measure. For instance, a decrease in 0.05 s in 10 m sprint time was associated with a 40% (90% CI 11 - 59%) increase in line breaks per match in the present study. Understanding the expected match performance improvement expected by a change in a physical measure has powerful implications for player development and monitoring.

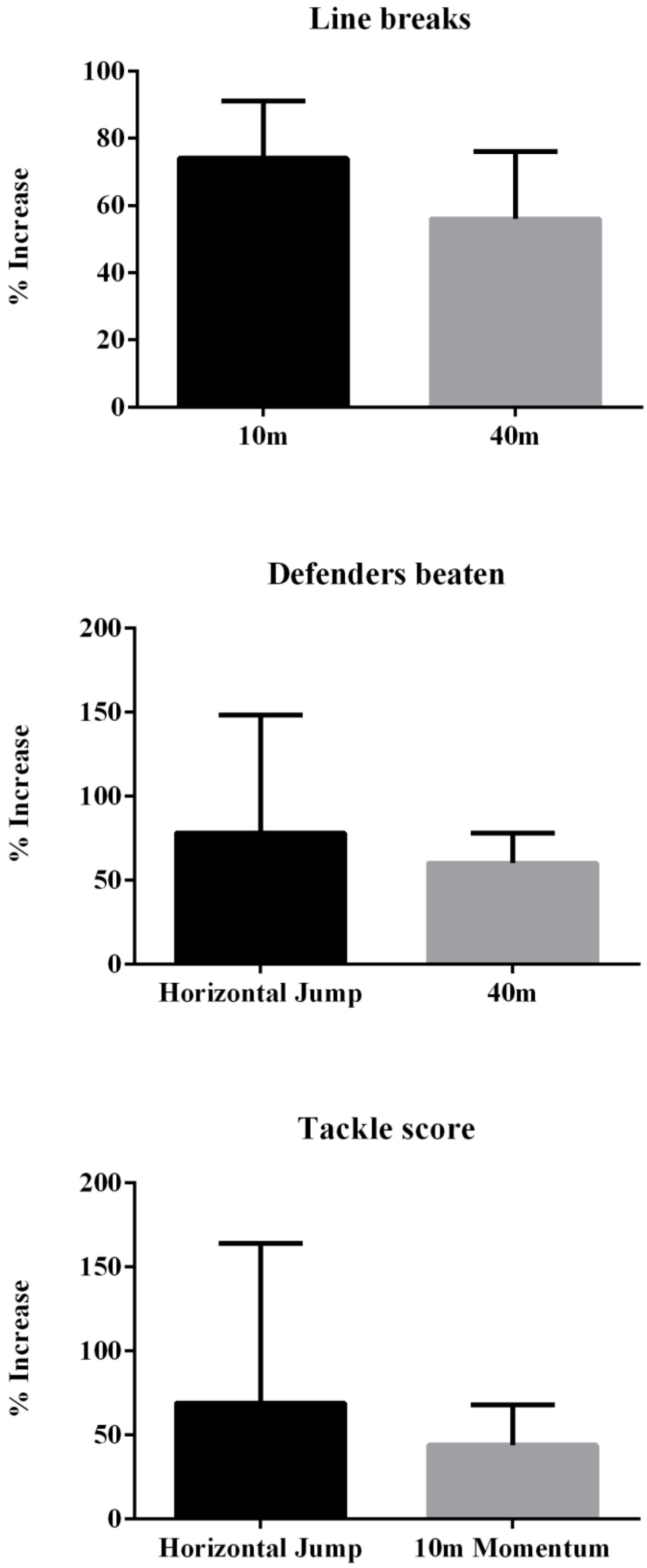


Figure 7.1 Percent change in match activity values as a result of 2 between-player SD change in physical assessment performance. Error bars represent 90% confidence limits.

7.4 Conclusion

The present study is the first to identify the relationship between physical measures and match activities in rugby sevens. The numerous moderate and large correlations suggest physical development is important to match performance in rugby sevens. Faster sprint times were associated with greater attacking performance (e.g. line breaks, tries scored, defenders beaten) while performance in defensive measures and rucks were associated with sprint, jump, and repeated sprint performance. Furthermore, greater repeated sprint performance was also associated with fewer handling errors and missed tackles and an increase in tackle effectiveness. Collectively, these findings demonstrate that well developed physical characteristics are associated with greater match performance.

Chapter 8

THE EFFECTS OF TWO POWER-TRAINING PROGRAMS ON THE SPRINT SPEED, MECHANICAL SPRINT CHARACTERISTICS, AND LOWER BODY POWER OF RUGBY SEVENS PLAYERS

Alex Ross, Nicholas Gill, John Cronin, Matt Cross

8.0 PRELUDE

A strong link between numerous physical characteristics and match performance indicators was observed in Chapter 7. Of these, sprint speed and lower body muscular power were related to measures of both attacking and defensive performance. As such, it would seem of use to investigate methods of improving sprint speed and lower body power in players concurrently training for rugby sevens competition. Therefore the focus of this chapter was to compare two four-week power-training programs on the sprint speed, mechanical sprint characteristics, and lower body power in rugby sevens players preparing for competition.

8.1 Introduction

Sprint speed and lower body power have been shown to be important physical qualities for performance in contact based field sports such as rugby union[34], rugby league [26], and rugby sevens [113]. In rugby sevens, players are required to perform multiple sprints throughout a match in addition to participating in collision scenarios such as tackles and rucks [109], highlighting an athlete possessing high levels of acceleration, maximal speed, and lower body power would be placed advantageously in competition situations. Coincidentally, lower body power capacity differentiates between athletes, with international level rugby sevens players performing 40 m sprints 4.4% faster, and producing 23% more peak power in a bodyweight countermovement jump when compared to their sub-elite counterparts [113]. Further, power and velocity measures have been shown to be highly related to sevens competition performance markers, with 40 m sprint performance being largely correlated with the number of line breaks made (r = - 0.51) and horizontal jump to tackle performance (r = 0.59) [114]. While it would appear that increasing the ability of the lower body to produce power would be beneficial to increasing performance markers critical to sevens competition, an understanding of the mechanical systems underlying power production is crucial to effective applied programming for athletes.

The peak power (P_{max}) a system can produce is portrayed in the linear force-velocity relationship (*F*-*v*), via which an athlete can increase their mechanical capacity by increasing either velocity or force capacity, or both [115]. Determining this relationship is important in individualising athlete prescription as it is possible that two athletes displaying similar peak power production may present significantly different combinations of velocity or force (i.e. high force-low velocity, or low velocity-high force profiles). Profiling this *F*-*v* relationship, in addition to peak power production capabilities, enables a more detailed view of athlete capabilities than traditional profiling methods and can provide programming guidance based on where athlete strengths and weaknesses lie [116]. Programming based on addressing imbalances in *F-v* relationships has the potential to increase performance, perhaps without a concurrent increase in P_{max}.

Recent studies [117-120] have improved the understanding of mechanical determinants of sprinting performance during both acceleration and maximal velocity phases. In contrast to previous thoughts, it appears that being able to technically apply ground reaction forces in a horizontal direction is a greater indicator of sprint performance than a greater magnitude of overall force. While profiling maximum power and *F-v* during sprinting has occurred mostly on instrumented [121, 122] or non-motorized [120] treadmill ergometer, a recent field method has been developed based on the instantaneous changes in speed during overground sprints [123]. This method allows external theoretical maximal horizontal force (F_o), maximal external horizontal power (P_{max}), theoretical maximal velocity (V_o), and the resultant force/velocity profile (*SFv*) to be determined during sprinting through centre of mass movement. This method has been implemented successfully in team sport situations, including elite rugby league and rugby union [124]. This method has been implemented in team sport situations, with a recent study [119]utilizing this method to identify the mechanical determinants of acceleration and maximal sprinting speed in youth soccer players. The authors reported acceleration was strongly related to F_0 and v_0 while maximal sprint speed was related to v_0 and P_{max}. While it seems that these mechanical variables are related to sprinting performance [119], no studies have examined the effect of different types of training stimuli (e.g. force/velocity) on mechanical profiles of athletes.

Previously investigated methods to improve sprinting performance and lower body power in rugby players have included resisted sprinting [125], traditional sprint training [126], jump squat training [127], and traditional strength training [128]. Both resisted and traditional sprint training [126] have shown effective at improving the sprint performance of rugby players concurrently performing strength, aerobic, and technical skill training. In another study involving concurrently training rugby players, complex training with a strength focus was shown to be superior to similar training with a speed emphasis in improving jump performance [129]. However, no studies have compared the effect of short-term training programs on the mechanical power production characteristics of athletes concurrently training for rugby sevens tournaments. Therefore, the impact of targeted training on these variables is unknown. Therefore, the purpose of this study was to compare the effect of two four-week power-training programs with either a high-force (force group) or high-velocity (velocity group) emphasis on the sprint speed, mechanical sprint characteristics, and lower body power of rugby sevens players.

8.2 Methods

Ten semi-elite rugby sevens players from the same New Zealand provincial representative team volunteered to take part in this study (Table 8.1). The study took place during an 8-week between-competition training phase. All players had a minimum of two year’s experience in speed, power and resistance training. All players were free of injury throughout the training study. Players were informed of the risks associated with the study and provided written consent prior to commencing the study. The Auckland University of Technology Ethics Committee granted ethical approval.

Table 8.1 Participant characteristics (mean ± SD) for force and velocity training groups

	Force	Velocity
Age (y)	20 ± 1	21 ± 2
Height (cm)	188 ± 6	186 ± 6
Weight (kg)	93 ± 8	96 ± 11
Predicted squat 1RM	153 ± 12	155 ± 18

1RM = One-repetition maximum

Prior to study commencement, all players participated in a three-week base building phase consisting of two 45 minute resistance training sessions per week (three to five sets of 4-8 repetition maximum [RM], 2 min rest between sets for 3-4 exercises), two 60 minute rugby sessions, two 45 minute field-based aerobic running sessions, and one speed and plyometric training session. In the last week of this base training phase, players performed a three repetition maximum in the half squat to determine estimated one repetition maximum in order to base specific training intensities on exercises during the intervention.

Players performed baseline testing five days prior to commencing the training study. Sprint testing was performed outdoors on an artificial track surface with players wearing standard training attire and athletic shoes (no spikes). Prior to the sprint testing, players performed a fifteen minute standardized warm up consisting of five minutes of easy jogging, five minutes of dynamic stretches (high knees, skips, bounds) and finished with 40 m sprints at 70, 80, 90% maximal effort. Players performed each sprint from a standing split-stance 30cm from the start line. A Stalker Acceleration Testing System radar device (Stalker ATS II, Applied Concepts, USA) was positioned 3 m behind the starting line at a height of 1 m above the ground. The radar device measured forward sprinting velocity at a rate of 46.9 samples per second and was operated through a connected laptop. Timing lights (Smart Speed, Swift Performance Equipment, AUS) were positioned at the start, 10m, and 40m. The players performed two maximal effort 40 m sprints with five minutes passive rest between efforts.

Timing splits at 10 m and 40 m were collected from the timing lights while radar data was collected using the STATS software provided by the radar company (Stalker ATS II Version 5.0.2.1, Applied Concepts, USA). A custom LabVIEW program (Version 11.0, National Instruments Corp., USA) was used to derive external force, velocity and power from the radar data using a previously described method [118, 123, 124]. Briefly, each sprint velocity (v) – time (t) curve was fitted by a mono-exponential function using least squares regression. From this signal, external horizontal force (F_h) was modelled over time by accounting for body mass and horizontal acceleration of center of mass (assuming zero net vertical acceleration), and combined with an estimation of friction force from the drag coefficient and frontal area of each player [130]. Instantaneous F_h and velocity were then plotted using linear regressions, from which F_0 and v_0 were determined as the axis intercepts of the linear plot, and P_{max} as the peak of the parabolic power-velocity curve (fitted by second order polynomial relationships). F_0 and P_{max} were expressed relative to body-mass. Maximum velocity (v_{max}) was expressed as the maximal velocity reached over the 40 m sprint. The fastest 40 m sprint of the two trials was included for analysis.

Lower body power testing consisted of a standing broad jump (BJ) and a countermovement jump (CMJ). For the standing BJ, players were allowed to use arm swing and were instructed to jump for maximal distance horizontally. Players were required to 'stick' the landing and jump distance was measured as the distance from the toes at take off to the back of the heel at landing, with three attempts permitted. For the CMJ, players held a 1kg wooden dowel (bodyweight) affixed to linear position transducer (Gymaware, Kinetic Performance, AUS). Relative peak power ($W.kg^{-1}$) was selected as the dependent variable. Players were permitted three jumps with the highest value recorded included in analysis.

8.2.1 Training

The training phase consisted of two conditioning programs, with either a high-force (force group) or high-velocity (velocity group) emphasis (Table 8.2). Each program consisted of two sessions per week matched for similar exercises, with the key difference between the two being a greater resistance used in the force group, which influenced the velocity at which each exercise was performed. Players were randomly assigned to either training group. In addition to their respective training program, all players also performed two upper body strength sessions (65-85% 1RM, three to five exercises, four sets of four to six repetitions), two 60-minute rugby skills sessions, and one 45-minute, field-based aerobic conditioning session.

Table 8.2 Overview of training exercises and progressions for two separate training programs in semi-elite rugby sevens players

Session One					
Force group (n = 5)	**Velocity group (n = 5)**	**Week 1**	**Week 2**	**Week 3**	**Week 4**
10 m Sled sprint (30 kg)	10 m Flying sprint (20 m build up)	2 sets 4 reps	3 sets 4 reps	3 sets 5 reps	2 sets 4 reps
Heavy sled push (10 m)	3-hurdle bound (60-75 cm)	3 sets 3 reps	3 sets 4 reps	4 sets 4 reps	3 sets 3 reps
Reverse Overhead Medicine ball throw	Reverse Overhead Medicine ball throw	3 sets 3 reps *F* – 12 kg *V* – 3 kg	3 sets 4 reps *F* – 12 kg *V* – 3 kg	3 sets 4 reps *F* – 15 kg *V* – 6 kg	3 sets 3 reps *F* – 12 kg *V* – 3 kg
Session Two					
Force group	**Velocity group**	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Countermovement squat jump	Countermovement squat jump	4 sets 4 reps *F* – 55% 1RM *V*– 20% 1RM	4 sets 4 reps *F* – 60% 1RM *V*– 25% 1RM	4 sets 3 reps *F* – 65% 1RM *V* – 30% 1RM	4 sets 3 reps *F* – 55% 1RM *V* – 20% 1RM
Band resisted horizontal jump	Horizontal drop jump (30cm)	4 sets 3 reps	4 sets 4 reps	5 sets 4 reps	4 sets 3 reps
½ Squat	Speed squat	4 sets 4 reps *F* – 75-80% 1RM *V* – 50% 1RM	4 sets 4 reps *F* – 80% 1RM *V*– 55% 1RM	3 sets 3 reps *F* – 85% 1RM *V* – 60% 1RM	3 sets 3 reps *F* – 90% 1RM *V* – 60% 1RM

F = Force training group; *V* = Velocity training group; 1RM = Predicted one-repetition maximum ½ squat

8.2.2 Statistical Analysis

All measures are presented as mean ± standard deviation. With the exception of speed timing splits, all measures were log-transformed to reduce the non-uniformity of error, and back-transformed to derive the percentage change of the training effects [90]. The magnitude of the training effects were derived from the standardized change in the mean of each performance measure by dividing the change in the mean by the between subject standard deviation of the baseline measure. Standardized changes were assessed through the following thresholds: 0.00-0.19 trivial; 0.20-0.59 small; 0.60 – 1.19 moderate; and ≥ 1.20 large [82]. Uncertainty in the size of an effect was assessed through 90% confidence limits, with an effect deemed unclear if the confidence interval crossed the threshold for substantially positive and negative effects [82]. Lastly, Pearson correlations were derived to assess the relationship between changes in 10 m and 40 m sprint times with mechanical sprint characteristics and jump measures.

8.3 Results

Baseline measures for all data are shown in Table 8.3. The force training group showed a small increase in BJ distance (2.7%) and a small increase in 10 m sprint time (1.0%) while all other changes were trivial (Table 8.4). The velocity training group showed small decreases in 10 m (-2.1%) and 40 m (-1.9%) sprint time, small increases in v_{max} (2.8%), v_0 (2.8%) and P_{max} (7.1%). There were moderate differences between the groups in change of 10 m sprint time, F_0 and P_{max} (Table 8.4). Standard deviations of the percentage change in the speed-training group were generally larger than the power-training group, suggesting there was more variance in the response to training in this group. A graphical representation of the changes in mechanical sprint characteristics of one player before and post-training is shown in Figure 8.1.

Table 8.3 Baseline and post-training 10m and 40m sprint time, mechanical sprint characteristics, and jump variables (mean ± SD) from two semi-elite rugby sevens training groups over a 4-week training phase

	Force		Velocity	
	Baseline	Post-Training	Baseline	Post-Training
Sprint time				
10 m (s)	1.75 ± 0.05	1.77 ± 0.05	1.73 ± 0.7	1.69 ± 0.10*
40 m (s)	5.19 ± 0.22	5.17 ± 0.20	5.14 ± 0.22	5.03 ± 0.20*
Mechanical sprint characteristics				
v_{max} (ms.$^{-1}$)	8.91 ± 0.64	8.95 ± 0.58	9.11 ± 0.69	9.36 ± 0.55*
v_0 (m.s.$^{-1}$)	9.25 ± 0.72	9.36 ± 0.58	9.47 ± 0.78	9.72 ± 0.61
F_0 (N.kg^{-1})	6.94 ± 0.72	6.64 ± 0.61	6.99 ± 0.37	7.31 ± 0.76*
P_{max} (W.kg^{-1})	16.1 ± 2.35	15.6 ± 2.00	16.6 ± 1.70	17.8 ± 2.6*
F/v Profile	-70.0 ± 10.0	-66.0 ± 8.78*	72.5 ± 13.1	73.2 ± 10.6
Jump variables				
BJ (cm)	257 ± 23.4	263 ± 16.3	265 ± 16.2	265 ± 18.7
CMJ (W.kg^{-1})	65.1 ± 4.3	66.9 ± 3.9	70.8 ± 5.9	71.4 ± 5.1

v_{max} = maximal velocity in 40 m sprint; v_o = theoretical maximal velocity; F_o = theoretical maximal relative horizontal force; P_{max} = relative peak power; BJ = horizontal broad jump; BW CMJ PP = bodyweight countermovement jump peak power *indicates a small difference from baseline

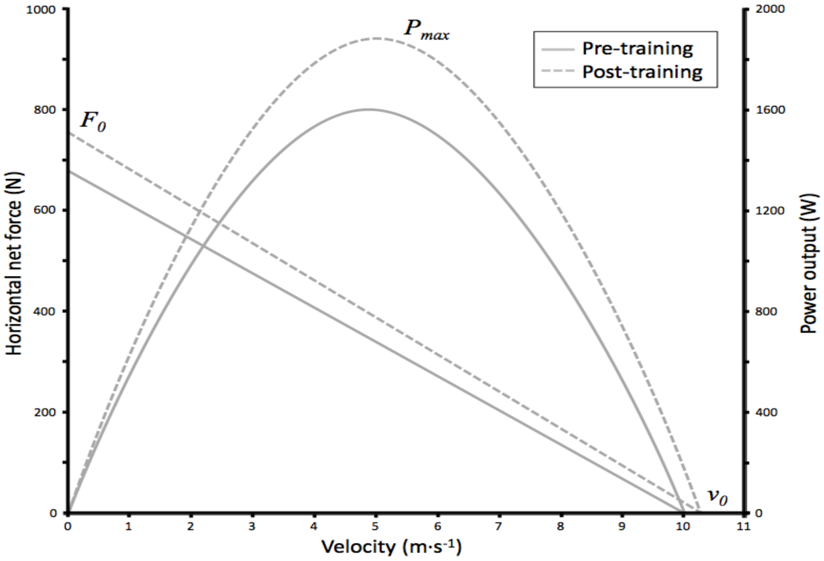
Table 8.4 Percentage change in 10 m and 40 m sprint time, mechanical sprint characteristics, and jump variables (% difference ± 90% confidence interval) from two semi-elite rugby sevens training groups over a 4-week training phase

	Force	Velocity	Force-Velocity difference
	% Change	% Change	% Difference in change
10 m (s)	1.0 ± 0.9*	-2.1 ± 2.2*	3.1 ± 2.2**
40 m (s)	-0.4 ± 0.4	-1.9 ± 1.4*	1.5 ± 1.5*
v_{max} (m.s^{-1})	0.4 ± 3.3	2.8 ± 2.7*	-2.3 ± 3.9*
v_0 (m.s.$^{-1}$)	1.4 ± 2.8	2.8 ± 2.9*	-0.1 ± 0.3*
F_0 (N.kg^{-1})	-4.2 ±1.7	4.2 ± 5.4	-8.9 ± 6.0**
P_{max} (W.kg^{-1})	-2.9 ± 3.4	7.1 ± 6.6*	-10.4 ± 7.1**
F/v Profile	4.4 ±2.7	1.4 ± 5.8	6.1 ± 6.4*
Broad Jump (cm)	2.7 ± 3.2*	0.3 ± 1.5	2.4 ± 3.2*
BW CMJ (PP)	4.0 ± 8.0	2.6 ± 9.0	3.1 ± 3.0*

v_{max} = maximal velocity in 40 m sprint; v_o = theoretical maximal velocity; F_o = theoretical maximal relative horizontal force; P_{max} = relative peak power; BW CMJ PP = bodyweight countermovement jump peak power; *indicates a small difference; ** indicates a moderate difference

Within all players, decreases in 10 m-sprint time following training were largely correlated with an increase in F_0 (r = -0.94) and P_{max} (r = -0.96) while decreases in 40 m sprint time were largely correlated with an increase in P_{max} (r = -0.64) and v_{max} (r = -0.79). Only small and trivial, unclear relationships were observed between BJ and CMJ changes and 10 m and 40 m performance.

Figure 8.1 A graphical representation of the force-velocity power profile over a 40 m sprint of one rugby sevens player pre-training and following four weeks of velocity based training



8.4 Discussion

This is the first study to our knowledge to compare the effect of high force and high-velocity based power-training programs on the speed, power, and mechanical sprint characteristics of rugby sevens players. The results of the present study revealed greater changes in the speed and mechanical sprint characteristics of rugby sevens players following training with a velocity emphasis. It appears improvements in both short (10 m) and longer (40 m) sprints are related to improvements in specific mechanical sprint characteristics that may offer utility in informing the programming of targeted sprint training programs.

The improvement in both 10 and 40 m sprint performance in the velocity group should be of interest to coaches and players given the importance of well-developed speed qualities in rugby sevens competition [29, 113]. The change (-2.1%) in 10 m sprint time following the 4-week training period in the velocity group is similar (-2.4%) to the results of 5-weeks of combined traditional and resisted sprint training in elite rugby union players [125]. The force orientated training group, however, failed to improve sprinting performance by any substantial degree; actually decreasing performance over 10 m. This finding is of particular interest, given short distance, high-force training (i.e. heavy loaded sled sprints) are widely considered directly specific to sprinting acceleration performance [131]. For example, West et al. [125] found combined traditional and resisted sprint training with 12.6% bodyweight elicited greater changes in 10 m and 30 m sprint performance than traditional sprint training alone, though both groups improved over each distance. With that said, previous studies [126, 132, 133] have shown traditional sprint training to be effective at improving sprint performance. It would appear that performance gains from sprint training may not be as simple as increasing loading to increase short distance sprint performance, and may serve as evidence to question the rationale for prescription of global loading protocols in the expectation of performance increases.

It has been proposed that resistance training utilizing high levels of horizontal force may have a greater effect on acceleration performance than vertical force-oriented exercises [120, 134, 135]. Essentially, the performance of these high-force movements, to align with the force end of the *F-v* relationship, should result in increased force capacity, and acceleration ability in the athlete. Interestingly, despite performing exercises with a significant horizontal force component (resisted sprint, sled push, band-resisted broad jump) the power group saw a substantial decrease in horizontal force production (-4.2%) following the training period. While the mechanism for this decrease in horizontal force production is unclear, it is possible that pre-training *F-v* and mechanical profiles may have to some degree dictated training response; that is, if a particular athlete presented a velocity orientated *F-v* profile (i.e. produces peak power at a greater level of velocity, and lesser lever of force) they will require less loading to promote optimal power production, and elicit increases in a rightward shift in the *F-v* curve. In essence; the greater load used for resisted sprints in the power group (~30% BW) may have not represented the most effective stimulus for peak power, and lighter loads may be more desirable for sprint improvement in rugby sevens players. Previous literature noting that horizontal force is a technical ability, rather than simply being related to magnitude of force production ability [117], may also serve to support the notion that simply increasing force production through high levels of loading may not improve sprinting performance across all athlete subsets.

The greater improvement in BJ and CMJ of the force group may be indicative of a greater specificity in the training exercises this group performed. Argus et al. [129] identified a greater improvement in BJ distance in a group of professional rugby union players following a 4-week complex training program with a strength emphasis as opposed to a group performing similar exercises with a speed emphasis. As it has been shown both BJ and BW CMJ are related to match performance [114], it would seem from the results of this study that power-training with a high-force emphasis is superior to training with a velocity emphasis for improving acyclic jump performance. As an additional note, while the primary training stimulus applied in the force training group was arguably specific and 'horizontal' in nature, the additional high-load vertically orientated movements (i.e. half squat) may have caused an interaction effect reducing the translation to sprinting performance. The increases in CMJ and BJ performance of the velocity training group may serve to support this contention.

Mechanical sprint analysis as used in the present study is a relatively recent method for analysing sprint performance [117]. Previous research has identified differences in the mechanical sprint characteristics of elite rugby union and rugby league players, as well as between positional groups (backs and forwards) within each group [124], suggesting the mechanical sprint qualities indicative of performance may vary between sports and playing positions. In agreement with our findings, a recent study [119] investigating the relationship between 10 m sprint time and maximal sprint performance (fastest 10 m split in a 40 m sprint) and mechanical sprint characteristics in youth soccer players identified strong relationships ($r = 0.57 - 0.96$) between 10 m sprint time and F_o and maximal sprint speed and P_{max} and v_o. The strong relationships between changes in mechanical sprint characteristics with changes in sprint performance across both 10 m and 40 m lends further support to the utility of mechanical sprint profiling through the methods used in this study. These findings may lend themselves to improved sprint profiling of athletes and enhance the individualization of subsequent training.

Although it is important to acknowledge the relatively small sample size in the current study (n = 10), it is worth considering that this sample is reflective of the nature of rugby sevens squads, which generally consist of less than 15 players per team limiting the opportunity for larger training groups. The short duration of the training intervention was also a limitation, however there is generally only a short period between rugby sevens competitions and this training period is reflective of the duration teams are afforded for targeted training. Furthermore, the concurrent training performed by the players during the study may have also influenced the results of the training programs; although in elite training situations it is unlikely a program, such as the one specified, will be implemented in isolation. Moreover, given the short duration of the study, a full deload period was not allowed and the slight taper in training volume may have not been sufficient in reducing accumulated fatigue; thus possibly reducing the training effects observed. Lastly, the incidence of non-responders to the training, particularly in the force training group, may be due in part to the random assignment of players to each group as opposed to placing players in training groups on the basis of their pre-training profile (force or velocity dominant). Future research should seek to investigate the effect of targeted training on the sprint performance and mechanical sprint characteristics based on pre-training mechanical sprint profiles.

8.5 Practical Applications

The following practical applications were derived from the outcomes of this thesis:

- In this small subset of semi-elite sevens players sprint and resistance training with a velocity emphasis appears superior to training with a power emphasis in improving speed over 10 m and 40 m in players concurrently training for rugby sevens.
- Response to the training may be dictated by code specific, individual specific, and pre-training *F-v* characteristics. Practitioners should consider prescription of loading and training modality based on individual athlete demands, with regards to their F-v profile and mechanical characteristics. Further research should investigate whether targeted training on based on pre-training mechanical sprint profiles and optimal

loading characteristics (i.e. load of P_{max}) increases performance over that of non-targeted training.

- It appears mechanical sprint profiling is useful in identifying the strengths and weaknesses of sevens athletes and could be used to inform specific training programs.
- The results suggest twice weekly, targeted training in addition to concurrent training is sufficient to improve performance of lower-body power based activity in rugby sevens players.

Chapter 9

SUMMARY, PRACTICAL APPLICATIONS AND FUTURE RESEARCH DIRECTIONS

9.1 General Summary

The overarching aim of this thesis was to assess the relationship between physical characteristics and match performance in rugby sevens. A comprehensive review of the current literature pertaining to match analysis and player characteristics in rugby sevens at the outset provided an overview of the current knowledge base, and exposed a considerable lack of research and provided directions for future research.

Based on the aforementioned gaps in the literature, the objectives were to firstly describe the global match demands of international rugby sevens and provincial level competition (Chapters 3 and 4) and profile and compare the anthropometric and physical characteristics of international and provincial level players (Chapter 5). The outcomes gleaned from these studies informed the subsequent chapters in which attacking and defensive performance indicators were developed (Chapter 6) and then analysed for their relationships with anthropometrical and physical characteristics (Chapter 7). Lastly, based on the outcomes from the previous studies (Chapters 5 and 7), the effect of two short-term training programs on the sprint speed and power of amateur rugby sevens players was assessed (Chapter 8). The following discussion describes the outcomes of these studies.

In order for physical, technical and tactical training programs to optimally prepare players for competition, specific match demands must first be understood. As a foundation for subsequent research, the focus of the initial series of investigations (Chapter 3 and 4) was to describe the physical, technical, and temporal demands of international and provincial rugby sevens matches and to identify whether differences exist between positional (forwards versus backs) groups and tournament rounds (Pool and Cup rounds). Match demands, both physical and technical, were mostly similar between international forwards and backs, with backs attaining greater maximal velocity (ES = 0.84) while forwards attended more rucks (ES = 0.26). There were trivial and unclear differences for all running variables and match activities between Pool and Cup tournament rounds, suggesting match demands remain stable despite an increase in opponent quality, however interestingly during Cup rounds a greater proportion of long ball-in-play sequences was observed. The running demands of international and provincial level players are mostly similar, though international players perform a greater frequency of sprints per match (ES = 0.80). Substantial (ES ≥ 0.19) differences were observed in all match activities with the exception of the total tackles affected. Collectively, the results of these investigations suggest match demands are similar between forwards and backs and between competition rounds, while international and provincial level competition is better distinguished by match activities as opposed to running demands.

One method to identify the anthropometrical and physical characteristics of importance within a sport is to compare elite and sub-elite players across a broad range of assessments. The purpose of chapter 5 was to describe and compare the anthropometrical and physical characteristics of international and provincial rugby sevens players as well as comparing forwards and backs across both groups. Clear, substantial differences were observed for all anthropometrical and physical characteristics between international and provincial players with the largest differences occurring in repeated sprint ability (ES = 2.33), 40 m sprint time (ES = 1.56), 50 kg countermovement jump peak power (ES = 1.87), and 20 m multi stage fitness performance (ES = 1.55). There were fewer and smaller differences between backs and forwards (ES = 0.10 – 1.29), height having the largest difference between playing groups. Anthropometrical and physical characteristics appear useful for distinguishing the competitive level of rugby sevens players and may be important for success during matches though these same measures are relatively similar between positional groups.

There is a necessity for understanding specific match factors related to success in rugby sevens in order to inform both tactical and physical training approaches. The purpose of Chapter 6 was to build on previous match analysis investigations (Chapters 3 and 4), to assess the defensive and attacking performance indicators related to points conceded and scored, respectively, in international rugby sevens matches. A total of thirteen performance indicators were assessed, with six indicators related to points conceded (defensive) and seven related to attacking performance (attacking). In terms of defensive indicators, tackle score showed the strongest relationship with a decrease in points conceded, with a two between-team SD increase equating to a decrease in 12.3 points (90% confidence limits (CL), ± 1.8) conceded per match. Line breaks had the strongest relationship with points scored, with an increase of 12.2 (± 1.4 points) per two between-team SD increase. Players and teams who are able to consistently affect dominant tackles and effectively contest defensive rucks are likely to concede fewer points while the ability to evade defenders and break the defensive line is indicative of teams who are able to score more points.

Previous chapters have established numerous physical characteristics likely important to success in rugby sevens players, specifically sprint and repeated sprint ability, lower body muscular power and maximal aerobic power as well as individual and team factors related to success in matches. Chapter 7 sought to build on these outcomes by investigating the relationship between physical characteristics and match performance. The ability to break the defensive line was largely correlated ($r = -0.51$) with 40 m sprint performance while RSA was strongly correlated with tackle score. These results provide practitioners with an enhanced understanding of the link between physical and match performance and provide useful information for overall player development programs.

With the finding in chapter seven of strong relationships between various measures of match performance and measures of sprint speed and lower body power, it would appear physical training programs for the rugby sevens player should place an emphasis on the development of these qualities. As such, the focus of chapter eight was to compare the effectiveness of two power-training programs on the sprint speed and lower body power of rugby sevens players. The four-week training program resulted in small decreases in 10 m (-2.1 %) and 40 m (-1.9 %) as well as increases in v_{max} (2.8 %) and P_{max} (7.1 %) for the velocity emphasis group while the force group improved only in the BW CMJ (3.1%). Rugby sevens players seeking to improve sprint speed should consider utilizing training programs with a high-velocity emphasis as opposed to a more force-dominant program. The strong relationships between changes in mechanical sprint characteristics and improvements in sprint speed lend support to the utilization of mechanical sprint profiling as a means to inform sprint training.

9.2 Practical Applications

The outcomes of this thesis have uncovered insight into several areas sport coaches and strength and conditioning coaches should consider when assessing and programming training for their athletes.

- The running demands and match activities of international forwards and backs are more similar than dissimilar; as such, position-specific training programs are likely not required.

- Teams aiming to train for the demands of international tournaments should focus on preparing for longer (>60 s) ball-in-play sequences indicative of cup tournament rounds.

- Sub-elite rugby sevens players and teams should focus on improving their skill execution (e.g. passing, tackling, rucking) during matches.

- Amateur players should focus on improving their physical characteristics, specifically 10 m and 40 m sprint speed, repeated sprint ability, lower body muscular power, and maximal aerobic power, to progress to international playing level.

- Physical preparation programs for forwards and backs should be largely similar, though backs should place a greater emphasis on sprint speed and forwards on lower body muscular power.

- Teams and players seeking to improve their defensive performance should focus their training on affecting dominant tackles and improving effectiveness at defensive ruck contests.

- To score more points, teams should select players effective at evading tackles and breaking the defensive line.

- To improve the ability to break the defensive line, players should place an emphasis on improving their 10 m and 40 m sprint performance.

- Improving horizontal jump distance and 40 m sprint performance is associated with an increase in the ability to evade tackles.

- Players who need to improve their tackling proficiency should aim to improve their repeated sprint ability and 10 m sprint performance.

- Players concurrently training for tournaments should include power exercises with a high-velocity emphasis when aiming to improve sprint speed.

9.3 Limitations

The following limitations of this thesis are noted:

- Chapters three, four, five, six and seven assessed a single international team and as such these results may not be indicative of all international teams.

- Chapters four and seven included a relatively low sample of games assessed in provincial level players however as there were fewer competitions at this playing standard relative to the international team it was not possible to include a similar sample of matches.

- The use of 4hz GPS units limited the amount of movement related metrics that could be reliably reported.

- The performance assessments in chapters five and seven were field tests performed in each teams respective training centre and as such are subject to the inherent limitations associated with field tests. However, these measures offer practical utility, as these are conditions and assessments reflective of regular training.

- A single tournament was assessed when analysing performance indicators across multiple teams in chapter six. Factors such as changes in temperature and climate, team selection and competition format between tournaments may influence playing tactics and as such the results of this study may not apply to all tournaments.

- The effect of a change in a physical performance assessment on match performance in chapter seven was a modelled outcome and is not necessarily reflective of an actual change in performance.

- The intervention period in the training study (Chapter 8) was only four weeks with no de-training period, allowing for the possibility of residual fatigue to influence the effectiveness of the training programs.

9.4 Future Research Directions

This thesis profiled the match demands and physical characteristics of rugby sevens players and examined various factors related to match performance. Numerous practical outcomes were derived from these investigations that have also provided directions for further research:

- Differences in the match running and technical profiles of better and worse performing international teams should be assessed to identify the specific physical and technical variables associated with success.

- Future studies of match analysis within rugby sevens should seek to incorporate internal measures (heart rate) to investigate the relationship between running and non-running (tackling, rucking) variables and internal training load. Analysis of the repeated sprint and repeated high intensity activities during matches is also required to better inform training.

- The performance indicators identified in Chapter 6 should be examined across multiple tournaments and teams to identify whether factors such as changes in opponent quality, weather and climate conditions, and tournament format influence these measures. These measures should also be assessed within a tournament to understand whether there is variability between tournament rounds.

- Numerous relationships between physical characteristics and match performance were identified in Chapter 7. The moderating effect of the match running performance should be examined to further improve the understanding of physical and match performance.

- Power training programs performed over longer training periods (6-12 weeks) should be investigated for their effectiveness compared to the relatively short (4 week) training program in Chapter 8.

- Future research should assess the stability of physical measures across an international rugby sevens season as well as the relationship between these changes and changes in match performance variables.

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APPENDICES

Appendix 1. Ethics Approval Forms

Appendix 1A. Ethics Application Number 13/214

(Chapters 3, 4, 5, 7)

AUT UNIVERSITY TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

AUTEC SECRETARIAT

16 December 2013

Nicholas Gill
Faculty of Health and Environmental Sciences

Dear Nicholas

Re Ethics Application: **13/214 Physical characteristics and match performance in rugby sevens.**

Thank you for providing evidence as requested, which satisfies the points raised by the AUT University Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 16 December 2016.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online throughhttp://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 16 December 2016;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 16 December 2016 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this. If your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply there.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor
Executive Secretary
Auckland University of Technology Ethics Committee

Appendix 1B. Ethics Application Number 14/309

(Chapter 8)

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

AUTEC SECRETARIAT

14 October 2014

Nicholas Gill
Faculty of Health and Environmental Sciences

Dear Nicholas

Re Ethics Application: **14/309 A comparison of a four-week force-specific and velocity-specific training on the force velocity profile of rugby sevens players.**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 7 October 2017.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 7 October 2017;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 7 October 2017 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Kate O'Connor
Executive Secretary
Auckland University of Technology Ethics Committee

Appendix 2: Consent Forms

Appendix 2A: Physical characteristics and match performance in rugby sevens

Consent Form	AUT UNIVERSITY TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Project title: Physical characteristics and match performance in rugby sevens
Project Supervisor: ***Nicholas Gill***
Researcher: ***Alex Ross***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 18th July 2013.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ I agree to participate in fitness testing prior to the rugby sevens season
- ○ I agree to allow the researcher to obtain competition statistics of me from video of rugby sevens tournaments
- ○ I agree to allow my provincial squad coach to view my results from fitness testing
- ○ I agree to allow the coaches from the New Zealand All Blacks Sevens team to view my results from fitness testing.
- ○ I agree to wear a GPS device under my playing jersey during competition matches if asked.
- ○ I agree to take part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Participant's signature :
....
Participant's name:
....
Participant's email for receipt of report:
....
Date:

Project Lead Researcher Contact Details:

Dr Nic Gill
Sports Performance Research In New Zealand (SPRINZ) at AUT Millennium Institute, Auckland University of Technology, Private Bag 92006, Auckland 1020
(+64) 027 4 888 699, ngill@aut.ac.nz

Appendix 2A: Effects of force-specific and velocity-specific training programs on the speed, power and force: velocity profiles of rugby sevens players

Consent Form	AUT UNIVERSITY TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Project title: Effects of force-specific and velocity-specific training programs on the speed, power and force: velocity profiles of rugby sevens players
Project Supervisor: ***Nicholas Gill***

Researcher: ***Alex Ross***

○ I have read and understood the information provided about this research project in the Information Sheet dated 2nd October 2014.

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

○ I agree to participate in a four week training intervention and fitness testing before and after the intervention

○ I agree to take part in this research.

○ I agree to allow the researchers to provide my testing results to the NZRU and my Provincial coaches (please tick one): Yes○ No○

○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Participant's signature :
....
Participant's name:
....
Date:

Appendix 3. Study Information Sheets

Appendix 3A. Physical characteristics and match performance in rugby sevens

Participant Information Sheet

Date Information Sheet Produced:

22nd August 2013

Project Title

Physical characteristics and match performance in rugby sevens

An Invitation

Hi, my name is Alex Ross, I am a PhD student in the Sports Performance Research In New Zealand (SPRINZ) at AUT Millennium Institute at the Auckland University of Technology. We are currently conducting a study assessing the physical characteristics of international and provincial rugby sevens players and how they relate to selected match skills.

What is the purpose of this research?

The purpose of this research is firstly to profile the physical characteristics of international and provincial level rugby sevens players, and secondly to investigate the relationship between these measures and selected on-field skills, as assessed through video analysis of competiton games. This project will form the third and fourth studies in my Doctoral thesis.

How were you identified and why are you being invited to participate in this research?

The participants for this project are required to be members of a New Zealand provincial rugby training squad or a member of the All Blacks Sevens training squad. An invitation was sent to your provincial union coach to distribute to potential participants and he has identified you as meeting the inclusion criteria for this project.

What will happen in this research?

You will be required to attend two testing sessions across a week as part of this research, which will each take approximately 90 minutes to complete. Testing will take place at your provincial union gym and training fields. The first session will consist of a 15 minute warm up followed by a series of maximal static and dynamic jumps performed standing on a force plate. You will then perform two sprints over 40 m with five minutes rest between each sprint. Next you will perform the Yo-Yo intermittent recovery test level two, a measure of anaerobic endurance. Lastly you will perform three repetition maximums in the bench press, squat and weighted reverse grip chin.
The second session will consist of measuring body composition (height, weight and 7-site skinfold test) followed by lateral and horizontal jumps. You will then perform a 6 x 30 m repeated speed test, performing a sprint every 30 seconds. Following a 30-minute rest, you will then perform the multi stage fitness (beep) test.
In the second, third and fourth study, match statistics from rugby sevens tournaments you participate in will be collected through video analysis. These match statistics will then be compared to the physical testing performance to assess what relationships exist between the physical performance and rugby performance.
You may be asked to wear a portable Global Positioning System (GPS) device during tournament matches to measure your movements, distance covered, and speeds. The GPS device is fitted into a lightweight vest and worn under your jersey.

What are the discomforts and risks?

There should be no significant discomforts or risks beyond those experienced during normal training and competition. You will likely experience shortness of breath and muscular soreness in your lower body.

How will these discomforts and risks be alleviated?

A comprehensive warm up will be performed prior to testing while a cool down will be performed following each testing session.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

- The data from the project will be coded and held confidentially in secure storage under the responsibility of the principal investigator of the study in accordance with the requirements of the New Zealand Privacy Act (1993). The participant information will be held securely for 10 years before being destroyed.

- All reference to participants will be by code number only in terms of the research publications. Identification information will be stored on a separate file and computer from that containing the actual data.
- Only the investigators will have access to computerised data.
- This information will be published in scientific journals, but at no stage will you be identifiable. The results will be presented as averages and not individual responses.
- The named results of all participants testing will be provided to Mr Mark Harvey, Strength and Conditioning coach for the All Blacks Sevens as well as to your respective provincial coach

What are the costs of participating in this research?

Participating in this research project will not cost you apart from your time which we greatly thank you for.

What opportunity do I have to consider this invitation?

- Please take the necessary time (up to 2 weeks) you need to consider the invitation to participate in this research.
- It is reiterated that your participation in this research is completely voluntary.
- If you require further information about the research topic please feel free to contact Dr Nic Gill (details are at the bottom of this information sheet).
- You may withdraw from the study at any time without there being any adverse consequences of any kind.
- You may ask for a copy of your results at any time and you have the option of requesting a report of the research outcomes at the completion of the study.

What opportunity do I have to withdraw from this study?

If you register for the study and complete the physical testing, but then decide you do not want us to use this information, please email us and we will delete it, otherwise your data will still be used for the research even if you do not complete the study in terms of the rugby game performances.

How do I join the study?

Participants will be recruited through their provincial union coaches who will receive the information sheet and consent forms via email from the primary researcher Alex Ross. You will also need to read and sign the consent form which will be collected in person on the day of testing.

You can contact the lead researcher Dr Nic Gill on ngill@aut.ac.nz or phone +64 027 4 888 699. Information on joining the study is also at www.sprinz.aut.ac.nz. You can also call 0800 SPRINZ to talk with Alex Ross, the researcher.

How do I agree to participate in this research?

If you agree to participate in this study, please complete and sign the attached consent form. This form will be collected in person on the day of testing.

Will I receive feedback on the results of this research?

A summary of your results from the testing and the averages of all participants will be provided to you via email. If you wish to receive your results, please provide your email on the attached consent form where indicated.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr. Nicholas Gill, ngill@aut.ac.nz; Sports Performance Research In New Zealand (SPRINZ) at AUT Millennium Institute, Auckland University of Technology, Private Bag 92006, Auckland 1020, Ph (+64) 027 4 888 699

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Kate O'Connor, ethics@aut.ac.nz, 921 9999 extn 6038.

Whom do I contact for further information about this research?

Primary Researcher Contact Details:

Alex Ross
Sports Performance Research In New Zealand (SPRINZ) at AUT Millennium Institute, Auckland University of Technology, Private Bag 92006, Auckland 1020E: alex.ross@aut.ac.nz
P: (021) 025 76003

Approved by the Auckland University of Technology Ethics Committee on *10/15/2013* AUTEC Reference number. 13/214

Appendix 3B. Effects of force-specific and velocity-specific training programs on the speed, power and force: velocity profiles of rugby sevens players

Participant Information Sheet

Date Information Sheet Produced:
2nd October 2014

Project Title

Effects of force-specific and velocity-specific training programs on the speed, power and force: velocity profiles of rugby sevens players

An Invitation

Hi, my name is Alex Ross, I am a PhD student in the Sports Performance Research Institute New Zealand at the Auckland University of Technology. We are currently conducting a study assessing the effect of two training programs on the speed and power of rugby sevens players. We are currently recruiting participants for this six-week study. Participation in this study is entirely voluntary and you may withdraw from participating at any time.

What is the purpose of this research?

The purpose of this research is to identify how different training programs affect speed, power and force: velocity profiles in rugby sevens players. This project will form the sixth study in the primary researcher's Doctoral thesis and will likely be submitted to a scientific journal for publication.

How was I identified and why am I being invited to participate in this research?

Your provincial union high performance manager identified you as someone who may be interested in participating in this study. The participants for this project are required to be members of a New Zealand provincial rugby training squad or member of the All Blacks Sevens training squad. You qualify for this criteria by being a member of one of these squads.

What will happen in this research?

You will be required to attend a total of ten sessions across a six-week period, consisting of a pre and post testing session and eight training sessions. The testing sessions will consist of two sprints over 40 m, a maximal countermovement horizontal jump, and five barbell jump squats with loads of bodyweight, 20 kg, 50 kg, and 100 kg. The training sessions will occur twice a week over a four-week period. One session will be conducted on a field and will consist of sprints, jumping activities, and medicine ball throws. The second training session will be performed in the gym and will consist of strength exercises for the lower limbs and resisted jump activities.

What are the discomforts and risks?

There should be no significant discomforts or risks beyond those experienced during normal training and competition. You may experience muscular soreness in your lower body.

How will these discomforts and risks be alleviated?

A comprehensive warm up will be performed prior to testing and training while a cool down will be performed following each session.

What are the benfits?

This study will provide you with information on your speed, strength, and power. The training program is aimed at improving these qualities as well. This study will form part of the primary researchers doctoral thesis and will aid in obtaining this qualification.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my privacy be protected?

This information will be published in scientific journals, but at no stage will you be identifiable. The results will be presented as averages and not individual responses. This data will be stored on a secure computer, and only authorised researchers will have access to this data. With your consent, the results testing will be provided to the New Zealand Rugby Union and your provincial coaches.

What are the costs of participating in this research?

There are no costs for participating in this research.

What opportunity do I have to consider this invitation?

You have a period of two weeks to consider participation in this research.

How do I agree to participate in this research?

If you agree to participate in this study, please complete and sign the attached consent form.

Will I receive feedback on the results of this research?

A summary of your results from the testing and the averages of all participants will be provided to you.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr. Nicholas Gill, *ngill@aut.ac.nz*; Auckland University of Technology, Division of Sport and Recreation, Private Bag 920006, Auckland; Ph (+64) 027 4 888 699

Concerns regarding the conduct of the research should be notified to the Faculty of Health and Environmental Sciences, AUTEC, Dr Valerie Wright St. Clair, *vwright@aut.ac.nz*, 921 9999 ext 6902.

Whom do I contact for further information about this research?

Primary Researcher Contact Details:

Alex Ross
Sport Performance Research Institute New Zealand
AUT Millennium Campus
E: alross@aut.ac.nz
P: (021) 025 76003

Approved by the Auckland University of Technology Ethics Committee on *10/10/2014* AUTEC Reference number 14/309

Appendix 4. Abstracts of Chapters as Published or in Review

Appendix 4a. Chapter 2. Sports Medicine

Ross, A., Gill, N., & Cronin, J. (2014). Match analysis and player characteristics in rugby sevens. *Sports Medicine*, *44*(3), 357–367.

Rugby sevens is a contact sport contested by two teams of seven players who compete over two 7-min halves, most frequently played in a tournament style. The IRB Sevens World Series is thought of as the preeminent rugby sevens competition in the world and has grown in competitiveness from its inception in 2000. The decision to include rugby sevens in the 2016 Olympics is likely to increase the global profile and participation in the game. Many rugby sevens players concurrently compete in 15-a- side rugby union as backs and loose forwards; however, a continued increase in the popularity of rugby sevens will likely see the emergence of the specialist rugby sevens player. Often thought of as the abbreviated version of rugby union, rugby sevens is played under nearly identical laws and on the same field dimensions as the 15-man code. However, research has shown the movement demands of rugby sevens and rugby union are dissimilar, with rugby sevens players spending a larger proportion of the game running at high intensity ($\geq$5 m.s^{-1}). Given the dissimilarity in match demands in conjunction with differences in the competition structure between the codes, it appears the considerable depth of literature specific to performance in rugby union may be of little value for the preparation of rugby sevens players. Investigations of the physical characteristics of rugby sevens players show backs are lighter and shorter than forwards, while players across all positions possess a lean body composition. International rugby sevens players have similar speed characteristics to rugby union backs across distances of 10–30 m; however, rugby sevens players appear to have superior intermittent aerobic endurance. Despite being of likely importance, little is known of the strength and power characteristics of rugby sevens players. Research into the speed and aerobic endurance

characteristics of rugby sevens players has not distinguished between backs and forwards and, as such, it is unclear whether differences exist between the position groups.

Appendix 4b. Chapter 3. Journal of Sport Sciences

Ross, A., Gill, N., & Cronin, J. (2014). The match demands of international rugby sevens. *Journal of Sports Sciences*. In Press

The purpose of this study was to quantify the global match demands of international rugby sevens and to compare the match demands of forwards and backs, and between tournament rounds. To assess the match demands, global positioning system (GPS) and video analysis were collected from 27 international rugby sevens players from the same team across an entire International Rugby Board Sevens World Series season. Differences in running demands and match activities between forwards and backs were mostly trivial and small (ES = 0.05–0.84) while differences in running demands and match activities between Pool and Cup rounds were trivial (ES = 0.001–0.12). Cup round matches showed an increase in long- duration ball-in-play sequences (proportion ratio 0.46). These findings suggest international rugby sevens forwards and backs experience similar match demands while overall match demands remain consistent across tournament rounds.

Keywords: time-motion analysis, rugby sevens, match analysis, mixed-model

Appendix 4c. Chapter 4. International Journal of Sport Physiology and Performance

Ross, A., Gill, N. D., & Cronin, J. B. (2014). A Comparison of the Match Demands of International and Provincial Rugby Sevens. *International Journal of Sports Physiology and Performance*. In Press

Purpose: This study compares the running demands and match activity profiles of international and provincial rugby sevens players. **Methods:** 84 rugby sevens players, consisting of 16 international players from the same team and 68 provincial players from 8 teams participated in this study. Global positioning system analysis was completed during international and provincial tournament matches. Video analysis was also used to quantify the individual match activities during tournament matches.
Results: Trivial to moderate differences were found in the running demands of international and provincial players, with internationals covering a greater distance at very high speed (ES = 0.30) and performing a greater frequency of sprints (ES = 0.80). Small differences were found between the two levels in all but total tackles (ES = 0.07), and defensive ruck effectiveness (ES = 0.64). International matches incurred a greater overall ball-in-play time than provincial matches (Proportion ratio = 1.32).
Conclusions: These findings demonstrate both physical and technical factors distinguish international and provincial rugby sevens, though overall match demands are similar.

Keywords: Rugby Sevens; Match Analysis; Amateur; Elite; Performance

Appendix 4d. Chapter 5. International Journal of Sport Physiology and Performance

Ross, A., Gill, N., & Cronin, J. (2014). Comparison of the Anthropometric and Physical Characteristics of International and Provincial Rugby Sevens Players. *International Journal of Sports Physiology and Performance*. In Press

Purpose: Anthropometrical and physical characteristics have been used to distinguish players of different competition levels and position groups; however, there is no literature within rugby sevens. The purpose of this study was to compare the anthropometrical and physical characteristics of international and provincial rugby sevens players and between forwards and backs. **Methods:** To assess whether differences exist, 65 rugby sevens players including 22 international players and 43 provincial level players were assessed for height, mass, body composition, speed, repeated sprint ability, lower body power, upper body strength, and maximal aerobic endurance during in-season preparation for tournaments. **Results:** Clear differences (2.8 – 32%; small to very large effect sizes) were observed in all anthropometrical and physical measures between international and provincial players, with the largest differences observed in repeat sprint ability (5.7%; very large effect size), 40 m sprint time (4.4%; large effect size), 50 kg squat jump peak power (32%; large effect size), and multi stage fitness test performance (19%; large effect size). Fewer and smaller differences (0.7 – 14%; trivial to large effect sizes) were found when comparing forwards and backs, with body height being the most discriminant characteristic (3.5%; large effect size). **Conclusions:** Lower level rugby sevens players should seek to improve their overall physical profile, particularly their repeat sprint ability, to reach higher levels in rugby sevens. Furthermore, positional status may have little importance when preparing for rugby sevens.

Keywords: Physical Profiling; Rugby Sevens; Speed; Strength; Power

Appendix 4e. Chapter 7. European Journal of Sport Science

Ross, A., Gill, N., Cronin, J., & Malcata, R. (2015). The relationship between physical characteristics and match performance in rugby sevens. *European Journal of Sport Science*. Accepted March 12

Rugby sevens is a sport that requires a multitutde of well developed physical fitness qualitites. Understanding the degree to which different physical characteristics relate to match performance provides practicioners with useful information for training program design. Therefore the aim of this study was to assess the relationship between physical characteristics and activities related to success in rugby sevens matches. Fitness-test and match activity data was collected from 40 international and provincial rugby sevens players. Sprint speed over 10 and 40 m had moderate to large (0.32 – 0.51) negative correlations (r) with line breaks, defenders beaten, and tackle effecetiveness. Repeated sprint ability and maximal aerobic capacity were moderately related to a measure of work rate (~0.38). Mixed-model analysis revealed a decrease of two between-player standard deviations in 10 m sprint time to be associated with an increase of 74% more line breaks per match. The results of this study suggest multiple physical characteristics are related to match performance in rugby sevens.

Appendix 4f. Chapter 8. International Journal of Sports Physiology and Performance

Ross, A., Gill, N., Cronin, J., & Cross M. (2015). The effects of two power-training programs on the sprint speed, mechanical sprint characteristics, and lower body power of rugby sevens players. Under review

Sprint speed and lower body muscular power are important attributes for many field-based team sports. While numerous studies have investigated the effect of different training protocols on sprint speed and lower body muscular power, little is known of the effect of power training programs on the sprint speed, mechanical sprint characteristics and lower body muscular power of athletes concurrently training for competition. This study compared the effects of force-specific and velocity-specific power training programs in semi-elite rugby sevens players (n=10). Following baseline testing, players were allocated to either the force-specific or velocity-specific training group and trained twice a week for four weeks. Following training, the velocity-specific group improved both 10 m (1.9%) and 40 m (2.1%) sprint times, while the force-specific group did not improve over either distance. The velocity-specific training group increased maximal velocity (2.8%) and relative power (7.1%) while the force-specific group decreased in horizontal force (-4.2%) and relative power (-2.9%). Broad jump distance was increased in the force-specific group (2.1%) and remained unchanged in the velocity-specific group. In conclusion, power training with a velocity emphasis appears to be superior to similar training with a force emphasis in improving the sprint speed and mechanical sprint characteristics of rugby sevens players.