Comparison of physical capacity between high level and low level contact groups in Rugby Union players

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Abstract

Rugby Union requires a high level of physicality as a variety of physical activities including contact such as tackling, scrummaging, rucking and mauling are needed. The mixture of activities, including those contact aspects, is unique and differs from many other team sports. Physical capacities such as anthropometry, strength, power, speed and aerobic capacity have been traditionally trained in Rugby Union due to their importance for improving performance and reducing risk of injury. This study examined differences in physical capacities (body composition, strength, power and aerobic capacity) between Rugby Union players who more frequently performed high level positive contact performance (HCP) and those who less frequently performed high level positive contact performance (LCP) during games. High level positive contact performance can be defined as contact performance which can gain territorial advantage during match-play. Correlation between physical capacities and contact performance indices was also investigated. Regarding contact performance indices, dominant ball carries, effective and dominant tackles were collected from game footage. A dominant ball carry meant that the ball carrier kept moving forward after collisions against tacklers. Likewise, in a dominant tackle, the tackler took the ball carrier down, moving them backwards. Similarly, an effective tackle meant that a tackler stopped forward momentum after collisions. Participants were recruited from the same province and played for either the provincial senior (n = 26) or Under 19 team (n = 21) in New Zealand through the 2018 representative season. Results showed that for relative positive contact performance (combined index based on dominant ball carry, dominant tackle and effective tackle) the HCP group displayed significantly greater body mass ($p = 0.024$). Greater body mass was also important for relative dominant ball carry

regardless of position (r = 0.434 for the forwards and 0.633 for the backs). Leaner body composition was helpful to perform relative dominant ball carries at the provincial level (r = -0.633). In terms of 1RM strength when players were divided based on the total number of positive contact performances, 1RM bench press and back squat were greater for the HCP group compared to the LCP group (p = 0.047 and 0.017 respectively). Likewise, those two strength capacities were related to dominant ball carrying for the forwards (r = 0.621 for bench press and 0.425 for back squat respectively), while only 1RM back squat was related to the number of positive tackles (combined index based on dominant and effective tackles,)performed for the backs (r = 0.537). Countermovement jump (CMJ) peak velocity was strongly correlated with relative dominant ball carries regardless of position (r = 0.471 – 0.637). It was also shown that aerobic capacity was not a significant contributor for contact performance.

Several practical applications can be suggested from these findings. Physical capacities such as body mass, maximum strength and CMJ peak velocity can be a predictor for game contact performance. This could assist with objective player selection in Rugby Union. Regardless of position or playing level, maximum lower body power focus training would be helpful for improving contact performance. Maximum strength type training for both upper and lower body would be particularly beneficial with forwards. Lower body maximum strength training may be beneficial for Under 19 players, while greater body mass with lower skinfolds could be important for provincial players.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or material which to a substantial extent has been expected for the award of any other degree or diploma of a university or other institution of higher learning, expect where due acknowledgement is made in the acknowledgements.

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Ethics Approval

Ethics approval was granted on 15th of October 2018 by Auckland University of Technology Ethics Committee (AUTEC): Reference 18/333 (Appendix A)

Chapter One

Introduction

Background

Rugby Union is a team sport in which players need to intermittently perform high intensity activities such as sprints, accelerations, decelerations, tackling, scrummaging, rucking and mauling [20] [42]. In those activities, the contact elements differentiate Rugby Union from the high intensity activities involved in sports like Soccer, Basketball and Netball. Following contact-involved activities there was greater impairment in power type exercises and greater perceived muscle soreness compared with non-contact activities [87]. Due to the types of activities that players need to play, not just strength but also power, speed and aerobic capacity have been recognised as important factors. Players in Rugby Union are not allowed to pass the ball forward and must carry it forward instead to score. This means it is necessary for attacking players to carry the ball strongly and break through the defence line, necessitating a number of tackles. Therefore, the quality of player's performance during the game when contacts (tackling and ball carrying) occur are crucial and this can be defined as game contact performance. Research has shown positional differences regarding type of contact activities with up to 200 to 300 tackles observed in a match [26] [31] [98]. While the forwards tended to be more frequently and repetitively involved in intense contact situations including scrum and line out, the backs usually waited for the ball to be provided by the forwards [31]. Furthermore, the forwards often demonstrated longer time spent engaging in contact type activities compared with the backs [31]. As a result, total work time and work frequency for the forwards were significantly greater than those for the backs [26].

The backs usually had greater rest periods in a game than the forwards, however they were required to cover more distance with high intensity sprinting [31] [26]. Contact activities were inevitable for all players regardless of position and it was key to winning the game to dominate opposite players in the contact area.

Physical capacities such as anthropometry, strength, power and aerobic capacity have been traditionally trained in Rugby Union as it is believed that these are important for improving performance and reducing risk of injury [20] [25] [37] [42]. For example, forward momentum is important for both tacklers and ball carriers to overcome opposition players and this momentum is correlated to velocity and mass of the players [47] [84] [93]. Furthermore, players need to have the capacity to repeat those contacts. Therefore, clearer understanding regarding how those physical capacities are correlated to game performance could help practitioners to provide more efficient and effective Strength and Conditioning (S&C) programmes for Rugby Union players. In this study, dominant ball carry (DB), dominant tackle (DT) and effective tackle (ET) were used to assess game contact performance.

As Rugby Union has become more popular and professional, the different competition levels have become more competitive and of higher quality [78]. Furthermore, the levels of internal competition between teammates in the same team to be selected in the starting fifteen have increased accordingly. For example, in New Zealand, there are many categories of competitions such as Super Rugby, Mitre 10 Cup, Under 19 competition and college 1st XV. Both Super Rugby and Mitre 10 cup are professional or semi-professional, whereas the others are technically amateur categories. Promising players are usually developed through academy systems based in each major province after high school to feed through to Mitre 10 and Super Rugby squads. Academies provide opportunities to develop physically and mentally both on and off field as professional athletes. Therefore, even the college 1st XV competition has become more competitive as players need to be recognised in that competition to be included in an academy program. Players must first be selected as starting members for their own team to get opportunities to play. Moreover, this competition within teams is important to survive in this environment as professional Rugby Union players. As sport industries have become more competitive, fair and equitable team selection process in sport teams should be used to maximise the potential for success [14].

Bradbury and Forsyth [14] researched how clear and solid selection process and criteria were used for athletes by New Zealand provincial sports coaches including Rugby Union. Although many coaches understood the concepts of ideal selection process and criteria, those were not actually utilised by most coaches [14]. This means player selection is still subjective and based more on coaching experience. Some studies have investigated the relationship between team selection and physical capacities in Rugby Union and League [34] [38] [40] [85]. However, those studies did not examine how physical capacities are related to contact performance but compared physical capacities between players selected by coaches based on experienced-based criteria and those who were not selected. For example, Sedeaud, Vidalin, Tafflet, Marc and Toussaint [85] concluded that taller players were more likely to get selected when two players have similar skill levels in Rugby Union. According to this conclusion, coaching experiences were more emphasised in team selection rather than objective physical capacities.

Therefore, more objective and accurate indicators for game performance may be useful for team selection in Rugby Union.

Research question

The overarching question of the thesis was how the physical capacities of players are related to game contact performance in Rugby Union?

Research aims

This study investigated the differences in physical capacities (body composition, strength, power and aerobic capacity) between Rugby Union players who more frequently performed high level contact performance (HCP) and those who less frequently performed high level contact performance (LCP) during match-play. Furthermore, the correlations between physical capacities and contact performance in game were examined. Physical capacities were also utilised in this study including anthropometry, one repetition maximum (1RM) for bench press and back squat for strength, the loaded CMJ for power and Yo-Yo intermittent recovery test level 1 (Yo-Yo IR) for aerobic capacity. Contact performance was assessed based on outcomes and/or technique of ball carries and tackles, which were coded from game footage.

Hypotheses

1) HCP players would have greater body mass, 1RM back squat, peak velocity during the loaded CMJ and aerobic capacity compared to LCP players at all levels.

2) Physical capacities such as body mass, 1RM back squat, peak velocity during the loaded CMJ and aerobic capacity would be significantly correlated to game contact performance.

Significance of the thesis

Few studies have focused on relationships between physical capacities and game performance in Rugby Union. Those studies reported correlation coefficients between physical testing results and game statistics [19] [89]. However, no previous study has examined relationships between physical capacities and game contact performance in Rugby Union. The current study determined the relationship between those variables as well as the magnitude of differences between two game contact performance groups in two different levels of players (Under19 or Provincial representative team). These two groups were defined as HCP and LCP based on game contact performance statistics. Medians were used as a cut-off point to split the two groups. The findings of this study showed how physical capacities are related to game contact performance and these findings could help both skills coaches and S&C coaches identify players who are capable of DB + DT + ET and effectively program physical training sessions to improve game contact performance. Awareness not only of how to improve physical capacities but also how those aspects are related to on field performance is crucial, especially for S&C practitioners. Furthermore, both the total number of DB + DT + ETs and the ratio of those relative to the total number of contact performances were used as the contact performance indices. Those two different indices can provide a greater range of analyses.

Limitations

1) Participants were recruited only from one province, therefore findings of this study might not be generalised to international settings.

2) The best results for each of the physical capacities during 2018 season were utilised in this study, thus all the physical testing results were not recorded at the same time.

3) Medians were used as cut-off points to divide participants into two different groups. However, the use of different cut-off points such as trisection and average points could produce different results.

Delimitations

1) Participants were playing for either Under19 or Provincial representative team, therefore they can be defined as elite athletes.

2) For all participants, every physical testing procedure was supervised and recorded by S&C coaches from the same provincial Rugby Union. Those coaches had shared criteria in terms of testing procedure, therefore this minimised variations between testers and maintained accuracy and validity of testing records.

Structure of the thesis

The current thesis consists of five chapters including introduction, literature review, method, results and discussion.

Chapter 1 includes background information on the importance of contact performance in Rugby Union and also the significance of this study. Furthermore, the research question, aim, hypotheses, limitation and delimitation are outlined in this chapter

Chapter 2 reviews previous research regarding physical demands in the game, game analysis, contact performance analysis and important physical capacities in Rugby Union players.

Chapter 3 provides details of participants, physical testing procedures, game analysis procedures, and statistical analysis.

Chapter 4 provides the results, including differences of physical capacities between LCP and HCP, and correlations between physical capacities and game contact performance statistics.

Chapter 5 compares the results of this study and findings with the previous literature. Practical application, recommendations, future direction of this research and summary are provided.

Chapter Two

Literature review

Physical aspects of Rugby Union players

Characteristics and physical demands of Rugby Union

Fifteen players play for both teams on a rectangular field of 94 - 100 metre length and 68 - 70 metre width. A match consists of two 40 minute halves, and average ball-in-play time has previously been reported as approximately 30 minutes for international matches [63], although there may be variability according to playing level and the characteristics of individual matches. Average duration of each ball-in-play time, which is the time when players continue to play until referee stops it, has been reported as 108.6 ± 8.5 seconds at the international level [76]. Furthermore, intensities of those activities and work ratio relative to rest in matches are increasing, which is one of the primary reasons for injury [5] [42] [78]. Therefore, appropriate progression regarding intensity of training and improving anaerobic capacity (maximum strength and power) as well as aerobic capacity are important to be able to repeatedly and accurately execute those high intensity activities through the entirety of the match minutes as well as prevent injury [20] [25] [37] [42].

Physical demands of Rugby Union have been researched using Heart Rate (HR) Monitors, Global Positioning Systems (GPS) and video analysis [16] [21] [22] [27] [28] [56] [64] [66] [69] [83] [90]. In terms of internal load, HR was mainly reported in previous research [16] [27] [28] [90]. Campbell, Peake and Minett [16] showed that mean HR during match-play across multiple games, which was approximately 150 bpm, was significantly greater than that during training, regardless of playing position in elite players. Similarly, HR max and mean HR were found for university players to be 192.2 ± 8.8 bpm and 165.0 ± 12.3 bpm respectively [90]. Total time spent in each HR zone was 15:06 ± 14:44 (within 141-152 bpm), 24:05 ± 13:13 (within 153-169 bpm) and 29:38 ± 20:35 (within 170-182 bpm) [90]. Deutsch, Maw, Jenkins and Reaburn [27] investigated positional difference of relative time spent in each HR zone (>95%, 85-95%, 75-84% and <75% HR max) for elite Under 19 players. The forwards (more than 55% of playing minutes) spent greater relative time in 85-95% HR max than the backs (33-41%). However, there was no significant difference in relative time spent in >95% HR max. On the other hand, backs spent more relative time in 75-84% and <75% HR max than forwards. In another study, professional forward players experienced greater time (18.1 ± 6.7 minutes and 37.9 ± 13.7%) in 85-92% HR max than the backs (10.8 ± 7.3 minutes and 22.8 ± 14.8%) [28]. This tendency was consistent with findings by Deutsch et al. [27], although percentage to the total match minute was different.

For external loads, running and contact performance have been investigated [16] [21] [22] [51] [56] [69]. Contact performance will be reviewed in the later part of this chapter. GPS can measure many different factors such as total distance, maximum speed, high intensity running distance, effort and so on, although metrics for each factor differ between studies, and were defined according to practitioner and researcher needs [16] [22] [51] [69]. Metrics are typically defined based on what practitioners and researchers need to monitor with athletes. Some such metrics are outlined as follows.

Average total distance was reported as 5400 ± 520 m and 5960 ± 690 m for forwards and backs respectively during match-play [69]. This was similar to the findings of another study, which showed that average total distances were 5370 ± 830 m and 6230 ± 800 m for forwards and backs respectively [22]. Regarding high intensity running (>20 $km \cdot h^{-1}$), total distance and efforts were reported as 180 ± 110 m and 25.6 ± 5.7 times for forwards and 400 ± 130 m and 28 ± 13 for backs respectively [69]. On the other hand, Cunningham et al. [22] demonstrated that efforts of high intensity running were 11.15 ± 5.06 and 26.44 ± 7.47 times for forwards and backs respectively. Regarding more specific positional differences, all positions other than Tight forwards showed significantly greater distance with high intensity running (18-19.8 $km \cdot h^{-1}$) than those in jerseys numbered 1 to 5, and Inside and Outside backs covered significantly greater distance with sprinting (>20.16 $km \cdot h^{-1}$) than Half backs [56]. Under 20 years-old Tight forwards and back three players demonstrated significantly greater relative high intensity running distance (>18.1 $km \cdot h^{-1}$) than their senior counterparts. However, senior midfielders covered significantly greater than Under 20 counterparts [21].

There have been more specific studies regarding running performance in Rugby Union [79] [80] [95]. Forwards have shown greater relative distance covered when defending than backs, however backs have covered more distance when ball was not playing [79]. Tee, Lambert and Coopoo [95] reported decrements in running performance between first and second halves in professional players. Although there was a reduction in relative distance covered for both forwards and backs (-13 ± 8 and 9 ± 7% respectively), only forwards displayed medium reduction in high intensity running distance by -27 ± 16% [95]. Reardon, Tobin, Tierney and Delahunt [80] examined physical demands over the single longest ball in play bout: relative distance covered during the single longest bout was significantly greater than average relative distance. Additionally, during the single longest bout the backs achieved greater distance covered, relative distance with high intensity running and maximum speed than the forwards over that duration [80]. Those findings are useful for practitioners to identify areas to work on for individual players and to program effective training sessions, especially for match preparation.

Anthropometry

Anthropometry refers to the collective of individual measurements for the human body, including height, body mass, skinfolds, circumference and length of a body part. Anthropometry has been measured in previous studies for a variety of team sports, including Rugby Union, Rugby League, Soccer, Australian football and American football [33] [43] [75] [77] [30].

Smart, Hopkins and Gill [88] investigated the anthropometric characteristics of Rugby Union players in New Zealand, including amateur, provincial and international level players, and reported the mean values of body mass and skinfolds for each position. Mean body mass and skinfolds were 113.5 ± 8.1 kg and 114 ± 26 mm for Props, 104.9 ± 6.4 kg and 102 ± 26 mm for Hookers, 109.4 ± 7.6 kg and 88 ± 29 mm for Locks, 101.6 ± 7.9 kg and 84 ± 30 mm for Loose forwards, 88.8 ± 9.2 kg and 74 ± 35 mm for Inside backs, 94.1 ± 6.3 kg and 74 ± 26 mm for Centres, and 89.2 ± 9.0 kg and 65 ± 25 mm for Outside backs. Those findings enable practitioners to understand current benchmarks and compare these with those from their own athletes.

Previous studies regarding anthropometry were conducted with the aim of summarising profiles, and comparing body mass and skinfolds between different positions, ages and the levels of players in team sports [88] [36]. In Australian football, it was concluded that small and medium-size position players were significantly lighter than medium and tall size position players respectively, which was a similar tendency to the difference in height between those positions [77]. A small difference in skinfolds was found between positions, however no consistency was shown regarding the relationship between position and skinfolds [88]. In Rugby League, while there was no significant difference in skinfolds among Under 14, 16, and 18 years players, however body mass displayed significant differences among these different age groups [36]. No significant difference was found regarding anthropometric characteristics between starters and non-starters in each age group [36]. In contrast, research in Rugby Union players demonstrated that higher-level players were likely to have greater fat-free mass and lower skinfolds than lower-level players [88].

Strength and Power

Strength and power are important physical measurements for contact sports such as Rugby Union, Rugby League, Australian and American football [9] [12] [23] [71] [81]. Because of the nature of contact sports, players need to develop physicality such as strength, power, body mass and speed for injury prevention and greater contact performance. More specifically, greater momentum into collisions are important to achieve positive outcomes after contact [47]. Momentum comprises velocity and mass which are products from strength, power and body composition. Types of strength measurements vary and include endurance (maximum repetitions), maximum (1RM) and isometric strength [68] [82]. Likewise, varied methods have been used for power assessments with ballistic exercise in the previous studies, including measuring displacement, force plate variables and linear position transducer measures [12] [23] [81]. Furthermore, these physical capacities have been measured through a variety of exercises such as bench press for upper body push strength [6] [88] [81] [102], Chin up for upper body pull strength [88] and Ballistic bench press throw for upper body push power [6] [102], back squat and box squat for lower body strength [8] [88] and power clean, squat and broad jump for lower body power [8] [29] [88] [81]. Upper and lower body maximum strength through 1RM bench press and back squat exercises, respectively, and lower body power through peak velocity during the loaded CMJ (20 – 40 kg) with a linear position transducer were used in this study.

Strength data of New Zealand-based Rugby Union players have been previously reported [88]. 1RM bench press and back squat were 133 ± 18 kg and 184 ± 19 kg for Props, 124 ± 17 kg and 175 ± 20 kg for Hookers, 121 ± 17 kg and 141 ± 21 kg for Locks, 119 ± 16 kg and 161 ± 21 kg for Loose forwards, 111 ± 16 kg and 141 ± 20 kg for Inside backs, 113 ± 15 kg and 151 ± 17 kg for Centres and 109 ± 16 kg and 145 ± 24 kg for Outside backs [88]. Relative strength of bench press and back squat can be also calculated relative to body mass. Previous studies have reported bench press and back squat relative values of 1.18 and 1.63 for Props, 1.19 and 1.68 for Hookers, 1.11 and 1.29 for Locks, 1.17 and 1.59 for Loose forwards, 1.26 and 1.6 for Inside backs, 1.2 and 1.6 for Centres and 1.22 and 1.62 for Outside backs in provincial level and above [88].

Lower body power assessment during various jump exercises has been performed with equipment such as force plates [59] [96] [104] and/or linear position transducers [11] [50] [67] [94] [104], with strong correlations (r = 0.9) and a typically low error of estimate (11.8%) between jump performance assessments through force plate and linear position transducer [74]. As force plates are expensive and not quite as mobile, linear position transducers may be more practical for practitioners [44]. Peak velocity during the unloaded CMJ through force plate has been measured for professional Australian football players, which was 2.56 ± 0.26 $m{\cdot}s^{-1}$ [104]. Thses were different from results with force plates from elite Rugby Union players and college athletes, which were 2.82 ± 0.26 $m{\cdot}s^{-1}$ and 3.07 ± 0.3 $m{\cdot}s^{-1}$ respectively [59] [96]. For the loaded CMJ with a linear position transducer, peak velocities during the 20 kg CMJ were 2.74 ± 0.12 $m{\cdot}s^{-1}$ and 2.80 ± 0.10 $m{\cdot}s^{-1}$ for professional Rugby Union forwards and backs respectively [50]. Furthermore, Barr, Gabbett, Newton and Sheppard [11] reported that international Rugby Union squads performed 2.83 ± 0.29 $m{\cdot}s^{-1}$, 2.52 ± 0.18 $m{\cdot}s^{-1}$ and 2.16 ± 0.19 $m{\cdot}s^{-1}$ during the 15, 40 and 70 kg CMJ respectively measured with a linear position transducer [11]. Another study recorded similar peak velocities for professional Rugby Union players as 2.60 ± 0.19 $m{\cdot}s^{-1}$ during the 40 kg CMJ with a linear position transducer [94]. Although there was no explanation regarding loading, international Rugby Sevens players have recorded greater peak velocity compared to the other studies, which was 3.61 ± 0.36 $m{\cdot}s^{-1}$ with a linear position transducer [67].

Strength and power in contact sport athletes have also been investigated to analyse the relationship between these variables and the positions, ages, and performance levels of players [8] [88] [36]. For example, Rugby League players competing in the national competition were17 % stronger in 1RM back squat and 11.5% more powerful in the loaded squat jump than those who were playing in the lower level competition [8]. Those physical assessments were common in contact sports and also used to evaluate the effects of different resistance training programmes [2] [18]. Findings from the previous study of Rugby Sevens players showed that a 6-week strength programme improved 1RM bench press and back squat by 11% and 13% respectively [18]. Furthermore, Argus, Gill, Keogh, McGuigan and Hopkins [2] found that the peak velocity performed by Provincial Rugby Union players during the loaded CMJ increased following 4 weeks of strength-power training, whereas there was a small decrease in the loaded squat jump following 4 weeks of speed-power training [2].

Aerobic capacity

Aerobic capacity is another important factor for Rugby Union as players are required to intermittently perform aerobic and anaerobic physical activity [25]. Aerobic capacity was often measured in intermittent team sports by controlled speed running tests such as the Multistage shuttle run, Yo-Yo IR and 30-15 intermittent fitness tests because these are practical for a large number of players [10] [25] [49]. Yo-Yo IR was used for aerobic capacity measurement in this thesis as subjects frequently performed this test. Yo-Yo IR has been previously used in Rugby Union players [4] [10] [23]: Australian semi-professional Rugby Union players achieved 1679 ± 302 m as a total distance [60]. Additionally, results from young (Under 21 years) English elite Rugby Union players were 1142.9 ± 353.9 m and 1384 ± 249.1 m for forwards and backs respectively.

The relationship between aerobic capacity and playing position, age, and playing levels has been studied in Rugby Union with similar tendencies to the other physical capacities [3] [24] [54]. Under 18 English elite Rugby Union forwards were likely to complete longer distances in Yo-Yo IR than Under 16 forwards. However, there was no clear difference between those age groups for backs [24]. This research also showed that backs were likely to have greater aerobic capacity compared to the forwards in each age category (Under 16, 18 and 21) [24]. In terms of playing level, although the difference was not significant, Professional Rugby League players completed longer total distance (1656 ± 403 m) in Yo-Yo IR than semi-professional players (1564 ± 415 m). Additionally, the results of aerobic capacity tests have been used to assess effects of conditioning training [92].

Game performance analysis in team sports and Rugby Union

As discussed earlier in this chapter, performance analysis has been conducted in different team sports using technologies such as video analysis, motion capture, coding software, GPS and HR monitor [15] [16] [27] [28] [46] [53] [57] [70] [90] [99] [103]. Coding software was used for assessing skill and technical aspects such as Scrums, Lineouts, Rucks, Mauls, Offloads, Kicks, Turnovers, Linebreaks, Tackles and ball carries [15] [53] [57] [103]. GPS was used for measuring external loads such as high intensity running distance, total distance, maximum speed, number of accelerations, and the number of body impacts [46] [70] [99], whereas HR monitor measured maximum and average HR and time spent in different HR zone [16] [27] [28] [90]. In the current study, every tackle and ball carry were coded from 22 games.

Contact events in Rugby Union

Contact events have been recognized as one of the main components of Rugby Union, and high levels of contact performance were related to playing level [41]. The main contact elements during match-play are tackling, ball carrying, rucking, mauling and scrummaging [31]. Based on this study's analysis, between 200 and 300 tackles occurred in a match, indicating an equal number of ball carries accompanied by contacts against tacklers were observed [100]. In terms of positional tendencies, forwards tended to perform a greater total and relative (per minute) number of contacts compared with backs [31] [56] [64] [66]. This tendency was due to a greater number of tackles and position-specific contact events for the forwards, such as contacts made in rucks, scrums, and mauls from lineouts [31] [64] [83]. However, backs experienced more ball carries into contacts than forwards [64]. There were more specific differences in contact between each position group. Jones, West, Crewther, Cook and Kilduff [56] showed that Tight and Loose forwards (n = 30 and 39 respectively) experienced a greater number of contacts than Half, Inside and Outside backs (19, 21 and 16 respectively). However, only Loose forwards demonstrated significant differences compared to the other backs [56]. This was consistent with findings from Lindsay, Draper, Lewis, Gieseg and Gill [64] who reported that Loose forwards made the greatest number of tackles, tackle assists, and rucks. On the other hand, Outside backs experienced the fewest number of those activities [64]. Interestingly, front rowers completed the fewest number of ball carries [64].

Several studies have examined contact intensities [66]. Contact loads measured by GPS in both DB and DT indicated significantly higher than neutral and passive tackles and ball carries [66]. Neutral tackle and ball carry indicated that a tackler stopped the forward momentum of the ball carrier, and there was no gain of area for either tackler or ball carrier from the point of contact. This contrasts with a passive tackle, wherein a tackle is made but the ball carrier moves forward from the point of contact. A passive ball carry is defined as one in which the ball carrier is tackled and pushed back from the point of contact. This could be attributed to the velocity into contacts as it shares a tendency with contact loads [66]. Moreover, the backs displayed greater velocity into contacts than the forwards [66] and this may be because the backs often have more distance from defenders.

Hendricks, Karpul, Nicolls and Lambert [48] compared acceleration and velocity of tacklers and ball carriers in tackles from different levels of Rugby Union games. Tacklers indicated average velocities and accelerations that ranged between 5.0 to 6.4 $m \cdot s^{-1}$ and -6.26 to -1.62 $m \cdot s^{-2}$ respectively, while ball carriers demonstrated 4.8 to 5.2 $m \cdot s^{-1}$ and -1.24 to 1.98 $m \cdot s^{-2}$ respectively. These were measured over 0.5 seconds to contact, which shows both tacklers and ball carriers decelerated towards contacts. Furthermore, there was no significant difference between those values between tacklers and ball carriers in most tackles. However, tackles were selected regardless of outcomes. Therefore, if the tackles were corrected based on outcomes, differences of velocities or accelerations between tacklers and ball carriers could have been observed. This was supported by Hendricks, Karpul and Lambert [47], who demonstrated the relationship between outcomes of tackles and the other biomechanical factors. The proportion of tackles dominated by tacklers (57%) was similar to the proportion of those in which tacklers displayed greater momentum (59%). Similarly, Takarada [93] concluded that ball carriers received more kinetic energy on their bodies when tacklers demonstrated more momentum, resulting in greater difficulty for ball carriers to maintain forward momentum and overcome tacklers.

Difference of momentum between tackler and ball carrier could be an indicator of tackle outcome, however further research is necessary to reveal the correlation between these two factors. Furthermore, tacklers more often indicated greater velocities compared to ball carriers (55%), while the body mass of tacklers was no greater than that of ball carriers in most tackles (32%) [47]. Although carrying the ball without being tackled by avoiding tacklers is the ideal attacking strategy to score tries, Sayers and Washington-King [84] stated that ball carrier's momentum is essential to overcome tacklers in tackles. The reason for this was the same as in the tackler's case: the greater momentum possessed by the ball carrier, the greater either force, or time, or both, is required for tacklers to stop the movement of carrying players. Furthermore, Van Rooyen et al. [100] also pointed out that ball carriers were more likely to dominate tackles when their momentum exceeded the tackler's momentum.

Tee et al. [95] indicated reductions in contact efforts (>5 $g \cdot min^{-1}$) between the first and second halves by -9 ± 17 and -10 ± 10% for forwards and backs respectively. However, there was no significant reduction of high intensity contact (>8 $g \cdot min^{-1}$) during the second half for both positional groups [95]. Therefore, fatigue induced during a game can influence low intensity contact performance. This contrasted with findings by Jones et al. [56], who found that mean total number of contacts between the first and second halves were similar in professional Rugby Union players (n = 12.3 ± 9.5 and 12.6 ± 9.8 respectively).

Furthermore, a player's ability in contact can positively influence the result of the game [97]. Tackling and ball carrying are key elements of contact in Rugby Union and Rugby League, which have been the focus of previous research [35] [39] [41] [47] [86] [91] [97] [100] [101]. Although both professional and amateur players indicated similar numbers of high intensity activities (contacts) [31], intensity such as momentum and impact in contact of professional players were greater than those of amateur players [47].

Contact performance assessment

Many studies have conducted contact performance assessment in terms of techniques, characteristics and biomechanics [35] [86] [98] [100]. For example, standardized technique criteria for tackling were utilised during the simple contact drill which included 8 criteria - (1) accelerating into the contact zone, (2) contacting the target in the centre of gravity, (3) contacting the target with the opposite shoulder to leading leg, (4) body position square/aligned, (5) arms wrapping around the target on contact, (6) leg drive on contact, (7) watching the target onto the shoulder and (8) centre of gravity positioned forward from the base of support) [35]. In another study, characteristics of ball carrying were investigated based on the outcome of contacts by using video analysis during the game [100]. For example, if ball carriers were pushed backwards and/or they did not make further forward gain from the point of contact against tacklers, those tackles were identified as effective tackles, using the direction in which the ball carrier was moving to, or falling down from the point where the contact occurred, as the assessment criterion.

From a biomechanical perspective, motion capture and instrumented tackle bags have been used to measure joint angles, kinematics and impact force [86] [98]. In those experiments, tacklers performed tackles against a suspended instrumented tackle bag or an opposing player running from 2.5 metres. The instrumented tackle bag was manually accelerated towards tacklers and controlled to resemble the momentum of ball carriers in the game. These measurements such as joint angles, kinematics and impact force could potentially be related to both performance and injury risk [86] [98]. However, the validity of using a suspended instrumented tackle bag to replicate a tackle situation is still questionalble.

<u>Relationship between contact performance and physical capacities</u>

Some studies have examined the relationship between performance level and other physical factors [19] [35] [47] [55] [89] [91]. When physical qualities were compared between elite and standard adolescent Rugby Union players, it was found that elite players demonstrated greater body mass, upper body maximum strength, sprint ability and aerobic capacity [55]. Therefore, it was concluded that playing at the elite level required development of those physical capacities, but these were also trainable at younger ages [55]. There were more studies which focused on the level of contact performance [35] [47] [91] [19] [89]. Gabbett [35] used standard criteria, described in the previous section, to examine the effects of fatigue on technique in a tackle drill, and results showed that fatigue induced by sport-specific activities negatively influenced technique. Hendricks, Karpul and Lambert [47] examined the relationship between tackler momentum and ball carriers and outcomes of contact events. Although higher body mass was not related to positive outcomes, it could be said that greater momentum positively affected outcomes.

Similarly, Speranza, Gabbett, Johnston and Sheppard [91] examined the relationship between strength and power profiles and tackling techniques by using a contact drill in Rugby League players. The findings revealed that 3RM back squat (r = 0.72 and 0.77) and bench press (r = 0.72 and 0.70) and the peak power during plyometric push up (r = 0.7 and 0.65) were positively correlated to the tackling techniques of provincial level and Under 20 players respectively.

Further studies have investigated the relationships between game statistics and common physical testing results for regional representative and professional Rugby Union players [19] [89]. Smart, Hopkins, Quarrie and Gill [89] reported that moderate correlations for the forwards were found between 20m sprint and metres advanced (r = -0.32) and evasion (r = -0.39), 10m sprint and evasion (r = -0.33), mean of 12 sprints and activity rate (r = -0.38), and body fat percentage and handling errors (r = -0.28). However, other physical qualities for forwards and backs had only small or trivial correlations [89]. Table 2.1 demonstrates the physical capacities and game statistics examined in the study by Smart et al. [89]. On the other hand, Cunningham et al. [19] revealed several large correlations between physical capacities and effort based and performance-based game statistics. Those factors are listed in Table 2.2. In the forwards, there were significant correlations between Yo-Yo IR and number of tackles made (r = 0.717), 40 cm drop jump and effective attacking rucks (r = 0.743) and turnovers (r = 0.89), 10 m sprint and half break (r = 0.718), 5 m sled drive and dominant collision (r = -0.705), 20 cm drop jump and carriers over the gainline (r = 0.726) and turnovers (r = 0.738) [19].

Table 2.1. Physical capacities and game statistics measured by Smart et al. (2014) [89]

Physical capacities	Game statistic items
10m sprint	Line breaks
20m sprint	Tackle breaks
30m sprint	Advantage line made
Mean sprint time from 9 sprints	Metres advanced
Mean sprint time from 12 sprints	Tries scored
Fatigue in the Rugby specific repeated speed test	Evasion
Power clean 1RM	Activity rate
Box squat 1RM	Attack first three
Bench press 1RM	Defense first three
Chin up 1RM	Successful tackles
Body fat percentage	Successful tackles
Fat free mass	Turnovers
	Successful passes
	Handling errors

Table 2.2. Physical capacities and game statistics from Cunningham et al., (2018) [19]

Physical capacities	Game statistic items
Body mass	Clean break
10m sprint	Half break
10m momentum	Tries scored
5m sled drive	Tackle success
40 cm drop jump reactive strength	Carries over the gainline
40 cm drop jump height	Dominant collisions
20 cm drop jump reactive strength	Effective attacking ruck
20 cm drop jump height	Turnovers
Single leg 20 cm drop jump reactive strength	Offloads
Yo-Yo intermittent recovery test level 1	Number of carries
Counter movement jump peak power	Number of effective attacking ruck
Counter movement jump relative peak power	
Counter movement jump height	Number of attacking first three
Single leg counter movement jump peak power	Number of defensive first three
Single leg counter movement jump height	Number of ball possession
	Number of passes

For backs, high correlations were shown between 10m momentum and dominant collision (r = 0.862) and offloads (r = 0.776), 5m sled drive and number of carries (r = -0.751), dominant collision (r = -0.792) and offload (r = -0.814), body mass and dominant collision (r = 0.915), peak power during CMJ and dominant collision (r = 0.749) and peak power during the single leg CMJ and dominant collision (r = 0.794) and offloads (0.728) [19].

As discussed previously, few studies have examined the relationship between contact event outcomes and physical testing [19] [89]. Furthermore, no study has investigated the relationship between contact performance and physical capacities for different levels of players. Therefore, the current study compared differences in physical capacities and correlations between Rugby Union players who displayed HCP and those who displayed LCP. HCP players were defined as those who performed greater numbers of positive contacts (DB, DT and ET) per given match minutes compared to LCP players. Findings of this study may be useful for more objectively identifying the players who are capable of superior contact performance and programming training strategy to improve contact performance.

Summary and Conclusions

Physical capacities such as anthropometry, strength, power and aerobic capacity have been researched and used as indices for assessing training adaptations in many contact team sports including Rugby Union due to their importance. Furthermore, physical demands have changed as athletes have become heavier, stronger, more powerful and faster. In Rugby Union, contact performance is a crucial contributor to winning the game, however limited research exists into the relationship between physical capacities and sport-specific contact performance. The findings of the current study will reveal how physical capacities of players are correlated with contact performance in Rugby Union.

Chapter Three

Methods

Participants

Forty-seven healthy male Rugby Union provincial and Under 19 players (forwards; n = 28, backs; n = 19) participated in this research. They played for provincial representative teams in New Zealand through the 2018 season (Mitre 10 Cup Premiership and Jock Hobbs Memorial National Under 19 Tournament). Participants regularly completed Rugby specific activities and resistance training (at least three days per week). Inclusion criteria was that the players must have played either 1) longer than a half (40 minutes and 35 minutes for Mitre 10 and Under 19 respectively) per game for data to be analysed, and played more than the minimum number of games across the season (3 games of Mitre 10 or Under 19) or 2) longer than 120 minutes total for Mitre 10 and 105 minutes total for Under 19 across the season to obtain sufficient contact performance statistics.

Physical Measures

All testing was conducted prior to game analysis by S&C coaches and Nutritionists from the same New Zealand Provincial Rugby Union (multiple times from preseason through to the completion of the 2018 seasons of Mitre 10 Cup and the Jock Hobbs Memorial National Under 19 Tournament). The best testing results for each component were utilised for analysis. The testers regularly conducted these assessments with the participants, which increased the validity and reliability of tests. Additionally, participants regularly performed all the testing as a part of physical testing for their own organisation and were familiar with the testing procedures. Participation of this study was completely voluntary. Participants were given information about this study including purpose, procedure, benefits and potential risks and signed the informed consent form. Ethical approval was granted by the Auckland University of Technology Ethics Committee.

Anthropometry

Body mass and skinfold thickness were measured for anthropometric data. Body mass was determined using the BWB-800P Doctor Scale (TANITA corporation, Tokyo, Japan) [62]. Skinfolds were calculated as the sum of the multiple sites of body using previously described methods [32] [43] [52] [30]. The skinfold measurer was required to be experienced and the same person to achieve consistency of measurements [75]. Skinfold thickness in the current study was assessed by the team nutritionist using the sum of skinfolds at 8 sites (biceps, triceps, subscapular, iliac crest, supraspinal, abdominal, front thigh and medial calf), by a qualified assessor using the established method by the International Society for the Advancement of Kinanthropometry [52]. Skinfolds were measured twice and the mean value used for further analysis. However, if more than 4% difference was observed, a third measurement was conducted to ensure reliability [105].

Power

After participants completed the warm-up and prior to strength testing, they performed the loaded CMJ with 20, 30 and 40 kg. A GymAware optical encoder (Kinetic Performance Technology, Canberra, Australia) was attached to a loaded barbell (20, 30 and 40 kg) to assess peak velocity. Warm-up (as described in the previous section) was already completed prior to CMJ and testing load ascended from 20 to 40 kg. Participants were instructed to jump as fast as possible with self-selected depth for the counter movements. Three repetitions for each load were performed, with 5 seconds rest between each repetition, and the highest peak velocity from 3 attempts was recorded as the result. Three minutes' rest was allowed between each set. The CMJ has been shown to be a valid assessment of peak velocity in the lower body [73], and previous research has shown ICC's of 0.97 for this variable [42].

Strength

Strength was measured using 1-3RM bench press and back squat following proper warm-up including self-myofascial release with foam rolling, dynamic stretching and light body weight exercise (squat, box jump, squat jump, forward lunge and push up). A maximum of 10 minutes' rest was allowed after power testing prior to strength testing. Once warm-up was completed, participants began 5-10 repetitions of back squat with approximately 30-50% of 1RM. Loads were progressively added towards 1RM, for example 70% of 1RM for 5 repetitions, 80% of 1RM for 3 repetitions and 90, 95 and 100% of 1RM for 1-2 repetition. Rest periods between sets were 2-5 minutes. 5 minutes' rest was provided between back squat and bench press testing. The same load progression was utilised to reach 1RM bench press. If participants failed to lift 1RM attempts, 2-3RM attempts prior to 1RM attempts were recorded as testing results. 1-3RM bench press and back squat was valid for assessing strength capacities of upper and lower muscles respectively [7] [8] [65] [71]. When participants completed 2-3RM, the Lander equation (1RM = (100×weight)/(101.3-(2.67123×reps)) [1] was utilised to estimate 1RM. The intraclass correlation coefficient (ICC) of this method has been shown to be greater than 0.96 [1].

Aerobic capacity

According to previous research, Yo-Yo IR was a valid test for assessing aerobic capacity [58] and highly reliable (test-retest coefficient of variation = 4.9%) [61]. For this study, participants completed the Yo-Yo IR following two days of recovery to minimise interference by fatigue from the other physical activities. The Yo-Yo IR is a sound controlled fitness test in which participants need to run 20 m shuttles within 3 beeps while there are rest periods between the last beep and the first beep for next level. Participants start running with the first beep and have to make the turn on the 20m line before the second beep. After turning around, until the third beep, they need to come back to the start line. The speed of each level progressively increases with consistent rest time between each shuttle. Testing was completed in the morning between 6am - 9am as participants regularly performed the same testing in this time period. On-field warm-up was led by the S&C coach after self-myofascial release with foam rolling. Participants completed animal walk exercises, dynamic stretching, jogging and acceleration drills in the on-field warm-up for approximately 10 minutes prior to performing Yo-Yo IR. This testing day was separate from the strength and power testing day for this study.

Performance analysis

Contact performance evaluation for individual players was based on tackle and ball carry performance analysis in the 2018 season's matches using analysis software

(SportsCode Elite version 6.5.1, Agile Sports Technologies Inc., Lincoln, Nebraska, USA). This software codes every tackle and ball carry from video footage. To examine individual performance in these two contact events, 8 different game statistics for individual players in 22 matches (12 games for Mitre 10 and 8 games for Under 19) were coded, displayed in Table 3.1. A DT meant the tackler had succeeded in taking down the ball carrier in a direction moving away from the tackler's try-line. An ET was defined as a tackle which prevented any forward progression of the ball carrier from the point of contact. Conversely, a DB meant that the ball carrier instead maintained forward progression after contact occurs. The median split technique was used as cut-off points for HPC and LPC groups, as this approach has been used in the previous research [45]. These groups were defined after the end of the 2018 season of each competition (after October 27th), based on game statistics from the entire season. These measurements have been used as contact performance parameters in previous studies [47] [101].

Table 3.1. Contact performance statistics

Contact performance statistics	Definition
Relative DB + DT + ET	Ratio of number of dominant ball carries + dominant tackles + effective tackles to total number of attempted ball carries and tackles
Absolute DB + DT + ET	Total number of dominant ball carries + dominant tackles + effective tackles
Relative DB	Ratio of number of dominant ball carries to total number of attempted ball carries
Absolute DB	Total number of dominant ball carries
Relative DT + ET	Ratio of number of dominant tackles+ effective tackles to total number of attempted tackles
Absolute DT + ET	Total number of dominant tackles + effective tackles
Relative ET	Ratio of number of effective tackles to total number of attempted tackles
Absolute ET	Total number of effective tackles
DB = dominant ball carries, DT = dominant tackles, ET= effective tackles	

Statistical analysis

Mean values and standard deviation were reported for each variable. Independent t-tests were used to compare the mean values of physical capacities derived from the contact performance groups (HCP and LCP). Based on eight different contact performance statistics, HCP and LCP were divided and the mean differences of each physical capacities were analysed. The Pearson product-moment correlation coefficient was used to examine relationships between contact performance and physical capacities. All analyses were conducted using SPSS software (Version 25; SPSS Inc. Chicago, IL). Effect size (Cohen's d; ES) was calculated with the magnitude of effects assessed according to the following criteria: d = 0.2 - 0.49 as small, 0.5 - 0.79 as moderate, d = or > 0.8 as large [17]. Likewise, the strength of relationship from the Pearson product-moment correlation coefficient was assessed according to the following criteria: r = 0.1 - 0.29 as small, r = 0.3 – 0.49 as moderate, r = 0.5 – 1.0 as large [17].

Chapter Four

Results

Mean values, SD and sample size of each physical capacity are displayed in Table 4.1. Injury or conflict with team schedules occasionally created differences in player availability for each physical capacity test. The reason for the fluctuation of participant numbers was that some players could not perform particular testing or could not progress loading because of injury.

Table 4.1. Mean values, SD and sample size of each physical capacity

	Mean	SD	N
Body mass (kg)	103.35	12.16	47
Skinfolds (mm)	90.66	24.19	39
Bench press 1RM (kg)	129.26	22.99	42
Bench press 1RM/body mass	1.24	0.16	42
Back squat 1RM (kg)	159.32	30.78	37
Back squat 1RM/body mass	1.47	0.40	37
PV20 (m/s)	3.23	0.25	40
PV30 (m/s)	3.02	0.21	38
PV40 (m/s)	2.78	0.22	36
Yo-Yo number of shuttles (level)	39.78 (17-5)	10.58	32
1RM = one repetition maximum, PV20, 30, 40 = peak velocity during Counter movement jump with 20, 30, 40 kg extra load			

<u>Difference in physical capacities between two different contact performance groups (HCP vs LCP)</u>

The t-test results are summarised in Table 4.2. The 95% CI (L/U) in Table 4.2 shows the lower and upper limits of mean difference between the groups (HCP and LCP). In terms of anthropometric characteristics, body mass was significantly different when participants were divided into two groups based on relative, absolute DB + DT + ET, and relative DT + ET ($p = 0.024$, 0.016 and 0.046 respectively). Furthermore, body mass demonstrated moderate differences for these three contact performances (ES = 0.613-0.745). There was no significant difference of body mass for the other performances. Similarly, skinfolds were significantly different when relative DT + ET split participants into two groups ($p = 0.002$) with a large ES (ES = 1.112). There was a moderate ES for relative DB + DT + ET (ES = 0.507), however this was not significant.

For 1RM strength, there were significant differences for bench press and back squat between median split groups by absolute DB + DT + ET (ES = 0.639 and 0.833 respectively). Additionally, 1RM bench press was significantly different for relative DB with a moderate ES (ES = 0.639). No other significant differences were observed for 1RM strength. None of the power assessment results showed significant differences.

Aerobic capacity displayed a moderate difference for relative DB + DT + ET and relative DT + ET (ES = 0.581 and 0.78 respectively), although the only significant difference was for relative DT + ET ($p = 0.041$).

Table 4.2. T-test results of physical capacities between two different contact performance groups (HCP vs LCP)

		DB + ET + DT (Relative)	DB + ET + DT (Absolute)	DB (Relative)	DB (Absolute)	ET + DT (Relative)	ET + DT (Absolute)
BM	Significance	0.024†	0.016†	0.144	0.208	0.046†	0.135
	Cohen's d	0.699**	0.745**	0.443*	0.381*	0.613**	0.454*
	95% CI (L/U)	1.205/15.963	1.762/16.411	-2.002/13.260	-2.806/12.549	0.158/15.103	-1.856/13.387
SF	Significance	0.132	0.818	0.553	0.472	0.002†	0.922
	Cohen's d	0.507**	-0.076	-0.197	-0.239*	1.112***	0.032
	95% CI (L/U)	-3.701/27.228	-17.856/14.197	-20.849/11.332	-21.524/10.157	9.306/37.118	-15.258/16.814
BP	Significance	0.051	0.047†	0.047†	0.363	0.104	0.051
	Cohen's d	0.628**	0.639**	0.639**	0.287*	0.519**	0.628**
	95% CI (L/U)	-0.066/29.022	0.187/29.292	0.187/29.292	-8.235/22.009	-2.603/26.906	-0.066/29.022
SQ	Significance	0.435	0.017†	0.151	0.084	0.536	0.484
	Cohen's d	0.263*	0.833***	0.489*	0.593**	0.208*	0.236*
	95% CI (L/U)	-16.13/36.685	5.711/54.816	-7.15/44.595	-3.133/47.869	-18.325/34.658	-17.23/35.674
PV20	Significance	0.197	0.220	0.167	0.474	0.803	0.871
	Cohen's d	0.426*	0.405*	0.457*	0.235*	-0.093	0.053
	95% CI (L/U)	-0.057/0.266	-0.062/0.261	-0.049/0.273	-0.105/0.222	-0.187/0.146	-0.151/0.178
PV30	Significance	0.278	0.225	0.096	0.278	0.920	0.566
	Cohen's d	0.367*	0.411*	0.570**	0.367*	-0.034	0.193
	95% CI (L/U)	-0.064/0.217	-0.055/0.224	-0.021/0.252	-0.064/0.216	-0.149/0.135	-0.101/0.182
PV40	Significance	0.309	0.088	0.243	0.242	0.879	0.335
	Cohen's d	0.354*	0.602**	0.407*	0.409*	0.053	0.335*
	95% CI (L/U)	-0.076/0.232	-0.020/0.275	-0.063/0.239	-0.063/0.24	-0.143/0.167	-0.079/0.227
Yo-Yo	Significance	0.122	0.311	0.889	0.659	0.041†	0.751
	Cohen's d	-0.581**	-0.376*	-0.051	-0.162	-0.780**	-0.117
	95% CI (L/U)	-13.269/1.644	-11.501/3.791	-8.315/7.24	-9.427/6.052	-14.797/-0.328	-8.986/6.547

DB = dominant ball carry, ET = effective tackle, DT = dominant tackle, CI = confidence interval, BM = body mass, SF = skinfolds, BP = bench press, SQ = back squat, PV20, 30, 40 = peak velocity during Counter movement jump with 20, 30, 40kg extra load, Yo-Yo = Yo-Yo intermittent recovery test level 1, †Significant difference between groups, * d = 0.2 - 0.49 as small, **0.5 - 0.79 as moderate, , *** d = or > 0.8 as large, L/U = lower/upper

Correlation between physical capacity and contact performance

Table 4.3 presents the correlation coefficients between physical capacity and contact performance in forwards and backs of the provincial and Under 19 teams. There were significant correlations between back squat and relative DB + DT + ET (r = 0.381), bench press and absolute DB + DT + ET (r = 0.314), 20, 30 and 40 kg CMJ peak velocity and relative DB (r = 0.425, 0.439 and 0,398 respectively), skinfolds and relative DT + ET (r = 0.371), body mass, bench press and absolute DT + ET (r = 0.363 and 0.336 respectively), skinfold and relative ET (r = 0.373) and body mass and absolute ET (r = 0.345). The strength of these correlations was moderate. The greatest correlation coefficient was reported between 30 kg CMJ peak velocity and relative DB for forwards and backs (r = 0.439).

Table 4.3. Correlation coefficients between physical capacity and contact performance in provincial and Under 19 teams (n = 47)

	DB + ET + DT (Relative)	DB + ET + DT (Absolute)	DB (Relative)	DB (Absolute)	ET + DT (Relative)	ET + DT (Absolute)	ET (Relative)	ET (Absolute)
BM	0.289	0.368**	0.2	0.223	0.231	0.363†**	0.09	0.345†**
SF	0.275	-0.011	-0.264	-0.169	0.371†**	0.044	0.373†**	0.071
BP	0.258	0.314†**	0.249	0.097	0.144	0.336†**	0.056	0.318**
SQ	0.381†**	0.288	0.273	0.146	0.21	0.284	0.097	0.27
PV20	0.267	0.187	0.425‡**	0.195	0.038	0.077	-0.022	0.047
PV30	0.253	0.216	0.439‡**	0.198	0.008	0.12	-0.095	0.074
PV40	0.304**	0.224	0.398†**	0.164	0.066	0.162	-0.093	0.103
Yo-Yo	-0.337	-0.153	-0.098	-0.18	-0.315	-0.126	-0.321**	-0.148

DB = dominant ball carry, ET = effective tackle, DT = dominant tackle, BM = body mass, SF = skinfolds, BP = bench press, SQ = back squat, PV20, 30, 40 = peak velocity during Counter movement jump with 20, 30, 40 kg extra load , Yo-Yo = Yo-Yo intermittent recovery test level 1, †Significant at <0.05, ‡significant at <0.01, **r = 0.3 – 0.49 as moderate, *** r = 0.5 – 1.0 as large

Table 4.4 shows the correlation coefficients between physical capacity and contact performance in the forwards of the provincial and Under 19 teams. Significant correlations were found between 20 and 30 kg CMJ peak velocity and relative DB + DT + ET (r = 0.49 and 0.531 respectively), body mass, bench press, back squat, 20, 30 and 40 kg CMJ peak velocity, and relative DB (r = 0.434, 0.621, 0.425, 0.459, 0.468 and 0.417 respectively), body mass, bench press and absolute DB (r = 0.506 and 0.413 respectively) and 20 and 30 kg CMJ peak velocity and relative DT + ET (r = 0.442 and 0.488 respectively). Large correlations were found between 30 kg CMJ peak velocity and relative DB + DT + ET, bench press and relative DB and body mass and absolute DB. The greatest correlation coefficient was observed between bench press and relative DB for the forwards (r = 0.621).

Table 4.4. Correlation coefficients between physical capacity and contact performance in the forwards of provincial and Under 19 teams (n = 28)

	DB + ET + DT (Relative)	DB + ET + DT (Absolute)	DB (Relative)	DB (Absolute)	ET + DT (Relative)	ET + DT (Absolute)	ET (Relative)	ET (Absolute)
BM	0.111	0.37**	0.434†**	0.506‡***	0.031	0.252	-0.035	0.262
SF	0.071	-0.168	0.185	0.183	0.168	-0.306**	0.36	-0.238
BP	0.163	0.289	0.621‡***	0.413†**	-0.118	0.185	-0.136	0.175
SQ	0.097	0.133	0.425†**	0.262	-0.1	0.048	-0.088	0.041
PV20	0.49†	0.338**	0.459†**	0.258	0.442†**	0.333**	0.278	0.278
PV30	0.531‡***	0.349**	0.468†**	0.324**	0.488†**	0.308**	0.283	0.242
PV40	0.396**	0.283	0.417†**	0.26	0.299	0.254	0.041	0.17
Yo-Yo	-0.118	-0.089	-0.015	-0.436**	-0.181	0.054	-0.47**	-0.04

DB = dominant ball carry, ET = effective tackle, DT = dominant tackle, BM = body mass, SF = skinfolds, BP = bench press, SQ = back squat, PV20, 30, 40 = peak velocity during Counter movement jump with 20, 30, 40 kg extra load , Yo-Yo = Yo-Yo intermittent recovery test level 1, †Significant at <0.05, ‡significant at <0.01, **r = 0.3 – 0.49 as moderate, *** r = 0.5 – 1.0 as large

Correlation coefficients between physical capacity and contact performance in the backs of the provincial and Under 19 teams are presented in Table 4.5. Correlations between body mass, 20 and 30 kg CMJ peak velocity and relative DB (r = 0.633, 0.637 and 0.605 respectively), and back squat and absolute DT + ET and ET (r = 0.537 and 0.539 respectively) were significant. Additionally, the strength of these correlations was large. The correlation coefficient between 20 kg CMJ peak velocity and relative DB was greatest for the backs.

Table 4.5. Correlation coefficients between physical capacity and contact performance in the backs of provincial and Under 19 teams (n = 19)

	DB + ET + DT (Relative)	DB + ET + DT (Absolute)	DB (Relative)	DB (Absolute)	ET + DT (Relative)	ET + DT (Absolute)	ET (Relative)	ET (Absolute)
BM	0.199	0.27	0.633‡***	0.437**	-0.096	0.095	-0.225	0.043
SF	-0.374**	-0.36	-0.344**	-0.425**	-0.313**	-0.247	-0.253	-0.231
BP	0.161	0.285	0.41**	0.155	0.012	0.333**	-0.058	0.304**
SQ	0.37**	0.474**	0.311**	0.237	0.255	0.537†***	0.189	0.539†***
PV20	0.297	0.102	0.637‡***	0.279	0.031	-0.049	-0.03	-0.077
PV30	0.088	0.114	0.605†***	0.242	-0.229	-0.008	-0.298	-0.048
PV40	0.128	0.171	0.536***	0.238	-0.129	0.086	-0.212	0.047
Yo-Yo	0.058	0.177	0.116	-0.033	0.069	0.276	0.079	0.277

DB = dominant ball carry, ET = effective tackle, DT = dominant tackle, BM = body mass, SF = skinfolds, BP = bench press, SQ = back squat, PV20, 30, 40 = peak velocity during Counter movement jump with 20, 30, 40 kg extra load , Yo-Yo = Yo-Yo intermittent recovery test level 1, †Significant at <0.05, ‡significant at <0.01, **r = 0.3 – 0.49 as moderate, *** r = 0.5 – 1.0 as large

Correlation coefficients between physical capacity and contact performance in provincial team players are exhibited in Table 4.6. Significant correlations were observed between body mass, Yo-Yo IR and relative DB + DT + ET (r = 0.498 and -0.473 respectively) and skinfolds, 20 and 30 kg CMJ peak velocity and relative DB (r = -0.633, 0.514 and 0.44 respectively), body mass, Yo-Yo IR and relative DT + ET (r = 0.564 and -0.478 respectively), and body mass, Yo-Yo IR and relative

ET (r = 0.526 and -0.538 respectively). The greatest correlation coefficient was reported between skinfolds and relative DB, although this was a negative correlation (r = -0.633).

Table 4.6. Correlation coefficients between physical capacity and contact performance in the provincial team (n = 26)

	DB + ET + DT (Relative)	DB + ET + DT (Absolute)	DB (Relative)	DB (Absolute)	ET + DT (Relative)	ET + DT (Absolute)	ET (Relative)	ET (Absolute)
BM	0.498‡**	0.207	-0.152	-0.104	0.564‡***	0.308**	0.526‡***	0.316**
SF	-0.047	-0.129	-0.633‡***	-0.347**	0.23	0.005	0.354**	0.057
BP	0.207	0.299	0.039	0.012	0.233	0.368**	0.168	0.36**
SQ	0.135	0.208	0.146	0.087	0.088	0.22	0.058	0.217
PV20	0.113	-0.138	0.514†***	0.108	-0.106	-0.256	-0.105	-0.276
PV30	0.156	-0.029	0.44†**	0.074	-0.055	-0.083	-0.125	-0.127
PV40	0.261	0.027	0.381**	0.067	0.069	-0.004	-0.098	-0.074
Yo-Yo	-0.473†**	-0.221	0.153	-0.038	-0.478†**	-0.233	-0.538†***	-0.269

DB = dominant ball carry, ET = effective tackle, DT = dominant tackle, BM = body mass, SF = skinfolds, BP = bench press, SQ = back squat, PV20, 30, 40 = peak velocity during Counter movement jump with 20, 30, 40 kg extra load , Yo-Yo = Yo-Yo intermittent recovery test level 1, †Significant at <0.05, ‡significant at <0.01, **r = 0.3 – 0.49 as moderate, *** r = 0.5 – 1.0 as large

Table 4.7 reports correlation coefficients between physical capacity and contact performance in Under 19 players. There was a greater number of significant correlations compared with provincial team players, such as between skinfolds, back squat, 20 kg CMJ peak velocity and relative DB + DT + ET (r = 0.798, 0,542 and 0.586 respectively), back squat and relative DB (r = 0.656), back squat and absolute DB (r = 0.535), skinfolds, 20 and 30 kg CMJ peak velocity and relative DT + ET (r = 0.688, 0.591 and 0.537 respectively) and 20 kg CMJ peak velocity and relative ET (r = 0.656).

Table 4.7. Correlation coefficient between physical capacity and contact performance in the Under 19 team (n = 21)

	DB + ET + DT (Relative)	DB + ET + DT (Absolute)	DB (Relative)	DB (Absolute)	ET + DT (Relative)	ET + DT (Absolute)	ET (Relative)	ET (Absolute)
BM	0.096	0.312**	0.235	0.423**	0.096	0.179	0.025	0.135
SF	0.798‡***	0.345**	0.539***	0.393**	0.668†***	0.234	0.507***	0.182
BP	0.358**	0.1	0.491**	0.182	0.202	0.023	0.218	0.013
SQ	0.541†***	0.332**	0.656†***	0.535†***	0.246	0.113	0.15	0.086
PV20	0.586†***	0.173	0.459**	0.152	0.591†***	0.148	0.656‡***	0.184
PV30	0.525***	0.224	0.51	0.299	0.537†***	0.123	0.531***	0.129
PV40	0.468**	0.209	0.474**	0.263	0.453**	0.126	0.448**	0.139
Yo-Yo	-0.219	-0.37	-0.282	-0.482**	-0.006	-0.198	0.136	-0.134

DB = dominant ball carry, ET = effective tackle, DT = dominant tackle, BM = body mass, SF = skinfolds, BP = bench press, SQ = back squat, PV20, 30, 40 = peak velocity during Counter movement jump with 20, 30, 40 kg extra load , Yo-Yo = Yo-Yo intermittent recovery test level 1, †Significant at <0.05, ‡significant at <0.01, **r = 0.3 – 0.49 as moderate, *** r = 0.5 – 1.0 as large

Chapter Five

Discussion

This study examined differences in physical capacities (anthropometry and strength, power, aerobic capacity) between HCP and LCP Rugby Union players and also analysed correlations between physical capacities and contact performance. As absolute contact performance indices are simple but relative indices such as successful ratio to total number of tackles, it was interesting to compare between absolute and relative data. The main findings from the t-tests were that the relative DB + DT + ET HCP group showed significantly greater body mass,1RM bench press and back squat than the LCP group. This index demonstrated the greatest number of significant differences in this analysis compared to the other indices. Additionally, when focused on physical capacities, body mass was significantly different between the two groups for three different indices, which were relative, absolute DB + DT + ET and relative DT + ET. Therefore, the significance of body mass difference for relative DB + DT + ET possibly caused by relative DT + ET and there may not be significant contribution from relative DB. From the correlational analysis, 20 and 30 kg CMJ peak velocity indicated moderate and large correlations with relative DB in forwards, backs and the provincial level. Interestingly the Under 19 group did not show significant correlations between PV 20 or 30 and relative DB. Body mass, 1RM bench press and back squat showed moderate and large correlations with relative DB for both forwards and backs. However, 1RM bench press and back squat for backs were not significantly correlated to relative DB. Only backs showed a moderate negative correlation between skinfolds and relative DB. The body mass of provincial players demonstrated moderate and large correlations to relative DB + DT + ET, DT + ET and ET. Finally, 1RM back squat had large correlations with relative and absolute DB as well as relative DB + DT + ET for Under 19 players.

Differences in physical capacity between HCP and LCP groups

Anthropometry

The findings revealed that body mass was significantly higher for the HCP group regarding relative and absolute DB + DT + ET, and relative DT + ET compared to the LCP group (p = 0.024, 0.016 and 0.046 respectively). Although there was no significant difference in body mass for relative DB, significant difference in body mass was found for relative DB + DT + ET. Therefore, this significant difference for relative DB + DT + ET could be mainly attributed to relative DT + ET. Although some differences were not significant, each contact performance indicated either small or moderate ES for body mass differences between HCP and LCP groups. Contrasting these findings, Hendricks et al. [47] have shown that body mass did not positively contribute to DB and tackle. Significant differences in skinfolds were observed only for relative DT + ET (p = 0.002 and ES = 1.112) in this study.

The HCP group demonstrated lower skinfolds than the LCP group for absolute DB with small ES, although this was not significant (p = 0.472 and ES = -0.239). However, there was no significant difference in skinfolds. For example, the HCP group for relative DT + ET showed higher skinfolds compared with the LCP group. According to the current findings, it can be said that greater body mass was more relevant than leaner skinfolds to positive game contact performance within this population. However, the higher playing level requires greater aerobic capacity, and tackle technique could be influenced by fatigue according to previous research [35] [55]. This suggests that a leaner body composition may still be important to performing repeated contact performance throughout a whole game at the elite playing level.

Maximum strength

Regardless of contact performance, the HCP group demonstrated greater 1RM bench press and ES for the difference of 1RM bench press between HCP and LPC groups for all contact indices was at least small (ES > 0.2). Bench press was significantly greater between two contact performance groups for absolute DB + DT + ET and relative DB (p = 0.047 and 0.047 respectively). Lower body strength findings were consistent with upper body strength. The HCP group performed greater 1RM back squat than the LCP group regardless of contact performance. ES for the difference of 1RM back squat between HCP and LPC groups for all contact indices was greater than small (ES > 0.2). The HCP group for absolute DB + DT + ET and absolute ball carry performed stronger 1RM back squat compared with the LCP group (p = 0.017 and 0.084 respectively). However, only the difference for absolute DB + DT + ET was significant. Relative DB (moderate ES) mainly showed differences in 1RM back squat for absolute DB + DT + ET as differences for absolute DT + ET indicated only small ES. The current results are similar to previous research by Speranza et al.[91] which reported that 3RM back squat, bench press and relative back squat was positively related to tackle abilities at both of the provincial and Under 20 level (r = 0.72, 0.72 and 0.86 respectively). This indicates that greater strength capacity could enable players to repeatedly perform proper technique in game, although in the current study, only absolute DB + DT + ET resulted in a significant difference between HCP and LCP groups. The other point is that greater strength capacity can be positively related to recovery ability from fatigue, so it enables players repeatedly perform contact. However, this requires further research.

A previous study used tackle technique criteria of arms wrapped around the target and leg drive on contact to assess tackles, because those were important when performing an ET[35]. Greater upper body maximum strength could help a tackler to maintain an arm wrap position around a ball carrier. Likewise, greater lower body maximum strength would be beneficial for a tackler to keep driving the legs forward against the ball carrier post collision. These factors may therefore be related to upper and lower body strength, so findings from the current study were not surprising. Furthermore, both back squat and bench press were significantly different between HCP and LCP groups for absolute DB + DT + ET. This means both maximum strength capacities were related to both tackle and ball carry performance.

Power

The hypothesis was that the HCP group would show greater loaded CMJ peak velocity. However, the current findings were not consistent with this. Regardless of loading on the barbell during CMJ, there was no significant difference in peak velocities between the two groups. However, the HCP group for relative DB performed greater 30 kg CMJ peak velocity ($p = 0.096$ and ES = 0.57). Likewise, greater 40 kg CMJ peak velocity was observed from the HCP group for absolute DB + DT + ET ($p = 0.088$ and ES = 0.602). Again, those were not significant, although a moderate ES was found. The t-test results were not consistent with that from the correlational analysis which found significant correlations between PV 20 or 30 and relative dominant ball carry for entire group, forwards, backs and provincial players. Hendricks et al.[47] found that greater momentum positively affected contact outcomes for both tackle and ball carry, although body mass was not related to outcomes. In other words, velocity into the collision may be important to achieve positive contact outcomes.

There were several factors regarding the power assessment which could change the findings of this research. As the median split analysis technique was used for the current study, using a different split point could produce different results. However, Goodale et al.[45] previously used the median split technique to divide participants into two different playing minute groups (high and low playing groups) in a study investigating physical characteristic differences in international women's Rugby Sevens players, so this technique was chosen for the current study. The other factor was using other jump testing (squat jump and drop jump) or measurements (jump height and reactive strength) as the previous study used [19]. However, there were reasons why CMJ peak velocity featured in the current study. Kinematically, CMJ is more similar to both ball carry and tackle compared with squat jump (concentric only focused jump). This is supported by Bobbert, Gerritsen, Litjens and Van Soest [13] who concluded that sport-specific dynamic movement were usually performed and improved with the counter movement. In a concentric-only focused jump, only the concentric contraction can be the source of force production, whereas CMJ and drop jump can use the stretch shorting cycle and elastic force from eccentric contractions [13]. This can produce greater force compared to the squat jump, which is supported by previous research [13]. However, the drop jump test will force participants to produce more force to handle an accelerated body. This may be more similar to the contact situation, as players need to handle reactive force after collisions. However, because participants regularly performed CMJ testing instead of drop jumps, and as there could be greater risk of associated injury with the drop jump test if participants were not accustomed to managing more force, the CMJ was used. Similarly, using a force plate could provide greater insights such as measuring reactive strength and other force-time characteristics. However, only the Gymaware optical encoder was available in this study and is a more cost effective method compared to force plates, especially in this applied setting. Previous studies in Rugby Union have used the Gymaware [1] [41] [73], which can be used to measure displacement, velocity and power output during both upper and lower body exercises such as bench press, squat and jump squat [1] [41] [73]. Gannon, Stokes and Trewartha [41] measured power output during hack squat for professional players, whereas McMaster, Gill, Cronin and McGuigan [73] reviewed ballistic exercise research including power clean, jump squat, CMJ, bench press throw and explosive bench press, and noted that these were often measured using the Gymaware.

Aerobic capacity

There was a significant negative relationship between aerobic capacity and relative DT + ET. This means that players who achieved a lower percentage of DT + ET were fitter than those who achieved a greater percentage of DT + ET. It could be concluded that aerobic capacity does not significantly affect contact performance at this level as no significant differences were found, similar to what was shown with skinfolds. Similarly, no significant correlation was shown in the current study. However, this differs to a previous study by Gabbett and colleagues [35] who concluded that fatigue induced by sport-specific activities negatively influenced the technical level of tackling. Therefore, the hypothesis that the HCP group would have greater aerobic capacity compared with the LCP group was not supported. Furthermore, this discrepancy between the hypothesis and the findings may be attributed to the fact that participants in this investigation did not play sufficient time in one game to become fatigued. However, aerobic capacity is still important to repeatedly move and prepare for doing work, in both attack and defense, in a fatigued state. This is supported by the previous study which compared aerobic capacity between elite and standard level of players [55]. At the same age group, Rugby Union players required greater Yo-Yo IR to play in the higher level of competition [55]. Therefore, other populations with higher playing levels such as professional and national representative teams could be interesting to conduct future research with to investigate the relationship between aerobic capacity and game contact performance.

Correlations between physical capacity and contact performance

Anthropometry

In the current study, body mass showed a significant correlation with absolute DT + ET and absolute ET for the entire group (r = 0.363 and 0.345 respectively). Furthermore, provincial and Under 19 forwards reported significant correlations between body mass and relative and absolute DB (r = 0.434 and 0.506 respectively). Similarly, backs from those two teams demonstrated moderate and large correlations between body mass and relative and absolute DB (r = 0.633 and 0.437 respectively), although only the relationship between body mass and relative DB was significant. This was consistent with the hypothesis. Previous research reported no significant correlation between body mass and contact performance for the senior elite professional forwards [19], however another study found that body mass was correlated to the number of dominant collisions in the game for the backs [19].

Interestingly, there was an inconsistent tendency between the different playing levels. Provincial players showed a significant correlation between body mass and relative DB + DT + ET, DT + ET and ET (r = 0.498, 0.564 and 0.526 respectively). On the other hand, there was no significant correlation between body mass and any contact performance for Under 19 players. As shown in previous research [47] [84] [93], forward momentum into contact is an important determinant for the outcome of the tackle and ball carry, and this momentum consists of velocity and body mass. One of the reasons why body mass had a correlation with contact performance for provincial players may be that greater body mass could be helpful in obtaining greater momentum into contact. At the Under 19 level, velocity into contact could compensate for the contribution from body mass to generate greater momentum into contact. However, this requires further research as speed capacity was not measured in the current research.

With respect to correlations between body composition and contact performance, the current study found that the entire group had a significant relationship between skinfolds and relative DT + ET and ET (r = 0.371 and 0.373 respectively). No significant correlation was found between skinfolds and any contact performance for either forwards or backs, although there were some moderate correlations. This is consistent with previous research [89]. There was no moderate or large correlation between percent body fat and percent of successful tackles for either professional forwards or backs in the previous study. Although there was a small correlation shown for the forwards between percent body fat and percent of successful tackle (r = -0.13), the data for the backs did not show even a small correlation [89].

Several significant correlations were shown for the different playing levels. Under 19 players showed positive correlations between relative DB + DT + ET and DT + ET (r = 0.798 and 0.668 respectively). Skinfolds had a negative correlation with relative DB for provincial players (r = -0.633). It can be concluded that lower skinfolds are a stronger contributor for repeating DB carry at the higher levels of Rugby Union.

Maximum strength

Back squat was correlated to relative DB + DT + ET (r = 0.381) and bench press was correlated to absolute DB + DT + ET and DT + ET in the current study (r = 0.314 and 0.336 respectively). This differs to Smart et al. [89] who concluded that professional forwards showed only a small negative correlation between back squat and successful tackle percentage (r = -0.11), while the backs displayed no correlation. Bench press was not significantly correlated to any contact performance. Regarding positional differences, the forwards reported a significant correlation between back squat and relative DB (r = 0.425) and bench press and relative and absolute DB (r = 0.621 and

0.413 respectively). Back squat was correlated to absolute DT + ET and ET for the backs (r = 0.537 and 0.539 respectively). However, the backs did not demonstrate any significant correlations for bench press.

According to these findings, upper and lower body strength are related to ball carrying ability for the forwards, while only lower body strength was related to the tackle. This may be because forwards perform different contacts and are tasked with different physical demands compared with backs [31] [56] [64] [66]. Like anthropometry, there were differences in the magnitude of correlations between different levels of player. While back squat did not show a significant correlation with any contact performance for provincial players, this correlated to relative DB + DT + ET, relative and absolute DB for Under 19 players (r = 0.541, 0.656 and 0.535 respectively). Furthermore, provincial or Under 19 players did not demonstrate any correlation between bench press and any contact performance. However, moderate correlations were found for provincial players between bench press and absolute positive and ET (r = 0.368 and 0.36 respectively) and for Under 19 players between bench press and relative DB + DT + ET and DB (r = 0.358 and 0.491 respectively). A previous study showed that provincial Rugby Union players demonstrated greater upper and lower body maximum strength and body mass than academy level players and this greater maximum strength could be attributed to greater muscle mass [1]. Even though maximum strength was not significantly correlated to contact performance for different levels of players in the current study, greater muscle mass might achieve greater body mass which was correlated to contact performance.

Power

According to previous findings, vertical lower body power may be a contributor for dominant contact performance [19]. In the current investigation, 20, 30 and 40 kg CMJ peak velocity was significantly correlated to relative DB (r = 0.425, 0.439 and 0.398 respectively). On the other hand, Smart et al. [89] utilised the power clean and reported that 1RM power clean was negatively correlated to tackle breaks for the forwards.

Specifically, the same tendency was observed in terms of ball carrying performance for both forwards and backs. With the forwards, large correlations were observed between 20, 30 and 40 kg CMJ peak velocity and relative DB (r = 0.459, 0.468 and 0.417 respectively), while the backs showed large correlations between those (r = 0.637, 0.605 and 0.536 respectively) as well. This is consistent with a previous study that tested jump height, reactive strength index and peak power output during CMJ and drop jump [19]. Findings showed during CMJ peak power output was related to dominant collision regardless of position (r = 0.600 for the forwards and 0.749 for the backs) [19]. Apart from bilateral CMJ peak power output, CMJ jump height, single leg CMJ peak power output and reactive strength index during 20 cm drop jump were strongly correlated to dominant collision for the forwards (r = 0.575, 0.568 and 0.589 respectively) [19], whereas the backs indicated that only single leg CMJ peak power had large correlations with dominant collision (r = 0.794) [19].

Inconsistent with ball carrying performance, there were positional differences in correlations between peak velocity and tackling performance in the current study. Peak velocity during 20 and 30 kg CMJ demonstrated significant relationships with relative DT + ET (r = 0.442 and 0.488 respectively) for the forwards, while the backs did not indicate any significant correlations between peak velocity and tackling performance. This could be because forwards often tackle opposition around the contact area with the shorter distance between tackler and ball carriers. On the other hand, there is often longer distance between the tackler and ball carriers for backs. Therefore, greater force production in a shorter time will be more important for forwards.

Provincial players showed significant correlations between 20 and 30 kg CMJ peak power output and relative ball carry (r = 0.514 and 0.44 respectively). In the Under 19 players 20 kg CMJ peak velocity was correlated with relative DB + DT + ET, DT + ET and ET (r = 0.586, 0.591 and 0.656 respectively). Forwards and backs among provincial players indicated significant correlations between peak velocity and relative DB. Conversely, Under 19 players displayed significant correlations between peak velocity and relative DB + DT + ET and relative DT + ET instead of DB.

It would be interesting to investigate other measures of power performance to focus on the correlation with contact performance indices. Previous research has used jump height, peak power output and reactive strength as previously discussed in this chapter [19] [42] [73]. The current study only used peak velocity to provide real-time feedback to participants as peak velocity was recorded in the regular team weights sessions. It was felt that the participants would have a clearer understanding of this measure were not familiar with measurements that could be obtained from the Gymaware.

Aerobic capacity

This study hypothesized that aerobic capacity would show significant correlations to game contact performance. In the current study, there was a negative moderate correlation between Yo-Yo IR and relative effective tackle (r = -0.321), while none of the correlation coefficients was significant for the entire group. When analysed by position, forwards and backs did not indicate any significant correlation, however, the forwards demonstrated two negative moderate correlations between Yo-Yo IR and absolute DB and relative ET (r = -0.436 and -0.47 respectively). Additionally, seven out of eight contact performances were negatively correlated to Yo-Yo IR for the forwards (r = -0.015 – -0.47). Conversely, seven out of eight contact performances displayed positive correlations to Yo-Yo IR for the backs (r = 0.058 - 0.277) although those correlations between contact performance and Yo-Yo IR for the backs were not significant. However, according to previous research, for the forwards Yo-Yo IR was strongly correlated with successful tackling percentage (r = 0.54) [19]. This could be due to those who have greater aerobic capacity would have more numerous chances for contact and performing proper technique in the contact area. However, this is inconsistent with the current findings.

When participants were split based on the playing level, most contact performances were negatively correlated to Yo-Yo IR for both groups. Differences between those two groups were that provincial players showed significant correlations between Yo-Yo IR and relative contact performance, DT + ET and ET (r = -0.473, -0.478 and -0.538 respectively), while Under 19 indicated no significant correlations to Yo-Yo IR.

Limitations

There were some limitations in this study regarding participants, data collection and analysis. Participants were recruited from one province, and the sample sizes were relatively small. Therefore, the current findings may not be suitable for generalising to other populations such as other provinces, different age groups or other countries. Also ,the physical data were collected at the different time points and the number of participants were different for each testing point. This means that those results might not be suitable for comparing between different physical testing results. Furthermore, provincial and Under 19 tournaments used different formats such as competition period, match minutes and number of games. This may have impacted the results. Similarly, there was an unequal number of participants between forwards and backs, which may have affected the results (N = 28 vs 19). The other limitation was that median split was used for the comparisons and using different cut-off points may have shown different results.

Future Research

For future studies, a greater number of participants and recruitment from different provinces in the same competition would be preferable to enable the broader research. However, in this case, the testing protocol would need to be standardised across provinces/franchises to maintain the accuracy of physical testing results. Ideally, collecting the physical data at a set timing during season or pre-season would allow the physical testing under the same conditions. Also, a greater number of participants for each position may have different correlations between physical capacity and contact performance.

Although it was not measured in the current study, horizontal power output such as broad jump and sprint performance would be interesting contributors to investigate the correlation with contact performance. According to previous research, forward momentum, consisting of velocity into the collision and body mass, were important for dominating the collision area in Rugby Union [47] [84] [93]. Speed, acceleration ability and horizontal jump ability (10 and 40m sprint and broad jump testing) might be correlated to velocity into the collision which contribute to DB + DT + ET. Furthermore, the rate at which players can achieve maximum speed and loaded acceleration ability, including the loaded sled towing performance, could be other aspects for further research. Rugby Union players need to be as fast as possible into the collision to make dominant contact, since they cannot control the distance between tackler and ball carrier. Therefore, it makes horizontal speed capacity a potential area of research. Loaded sled towing could also replicate the post collision situation wherein players still need to maintain forward momentum to dominate opposition players. Another potential area for study is intervention research to focus on actual effects of physical capacity improvement on contact performance. This would entail more long-term studies, in which the contact performance indices could be compared between pre and post training intervention. As discussed in the earlier part of this chapter, measuring reactive strength and peak power output with a force plate during drop jump testing would also be interesting. Reactive strength during drop jump could show different relationships with the contact performance indices, because players would be required to absorb greater reactive strength than CMJ while at the same time generating force to jump as high as possible.

Conclusion

In conclusion, each physical capacity has a different magnitude of relevance with contact performance.

- It appeared that greater body mass was particularly important for relative DB for forwards and backs.
- Lower skinfolds might enable Rugby Union players to perform relative DB at the provincial level.
- Maximum upper body and lower body strength were related to relative DB for the forwards, while backs showed significant relationship between lower body strength and absolute DT + ET.
- Lower body strength was significantly related to perform relative DB + DT + ET , relative and

absolute DB for Under 19 players , whereas no significant relationship was found at the provincial level.

- Loaded CMJ peak velocity was strongly correlated to relative DB across different groups except for Under 19.
- No positive significant relationship between Yo-Yo IR and any indices were reported.

Practical Applications

For practitioners, the current findings will help with evaluating players with greater capacity for DB, dominant and effective tackling, and also with effectively programming training sessions to focus on improvement of positive game contact performance for individual players. For example, team selection would benefit from the current findings that greater body mass and CMJ peak velocity were significantly correlated to DB performance. Particular physical capacities such as body mass, both upper and lower body maximum strength, and CMJ peak velocity can be relevant game contact performance without actually playing games, because those characteristics were correlated to DB + DT + ET. This would enable practitioners or coaches more reasonable and objective player selections based on physical capacities. Furthermore, this will help players to understand how the physical training that they conduct regularly is related to game contact performance. This could help to maintain motivation at a high level for physical training.

More specifically, greater body mass, 1RM bench press and back squat and the loaded CMJ peak velocity are important for performing DB. Furthermore, for the forwards, greater peak velocity is also beneficial for relative DT + ET, whereas only greater body mass and CMJ peak velocity are significant contributors to DB for the backs. Increased 1RM back squat strength can enhance the number of dominant and ET for the backs. Overall, it would seem that regardless of position, resistance training aimed at increasing muscle mass and improving lower body power output would be helpful for achieving improved DB + DT + ET and improving maximum strength for upper and lower body would be particularly beneficial with the forwards.

There are different key elements to improving contact performance according to playing level. Working on fat-free mass and peak velocity during 20, 30 and 40 kg CMJ could be potential solution for provincial players to improve DB performance, while training programmes for greater body mass (muscle mass) might help them to improve DT + ET. Contrasting these suggestions, for Under 19 players, the maximum strength type work and power focused type training maybe beneficial for DB . Lower body power training (20 and 30 kg CMJ) is important for DB + DT + ET for both forwards and backs. Overall, this study revealed that although different player groups have different tendencies regarding relationship between physical capacity and game contact performance, CMJ peak velocity were strong contributors for DB except in Under 19 players. Therefore, appropriate physical capacities should be focused on according to player groups when S&C coaches are working with Rugby Union players.

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Appendices

Appendix A: AUTEC approval

AUT
TE WĀNANGA ARONUI
O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
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15 October 2018

Michael McGuigan
Faculty of Health and Environmental Sciences

Dear Michael

Re Ethics Application: **18/333 Comparison of physical capacity between high level and low level contact groups in Rugby Union 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 15 October 2021.

Standard Conditions of Approval

1. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/research/researchethics.
2. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/research/researchethics.
3. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/research/researchethics.
4. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation, then you are responsible for obtaining it. You are reminded that it is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

For any enquiries, please contact ethics@aut.ac.nz

Yours sincerely,

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

Cc: watarugjg1011@gmail.com

Appendix B: Participation Information Sheet and Consent form

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Participant Information Sheet

Date Information Sheet Produced:

17 September 2018

Project Title

Comparison of physical capacity between high level and low level contact groups in Rugby Union players

An Invitation

Kia Ora, everyone.

I, Wataru Hiramatsu, am a Masters student based at the Sports Performance Research Institute New Zealand (SPRINZ) at AUT Millennium, School of Sport and Recreation, Faculty of Health and Environmental Sciences. I would like to invite you to participate in a research project to compare differences in physical capacities (strength, power, speed, aerobic fitness and anthropometry) between rugby players who display greater numbers of positive outcomes in tackling and ball carrying during a rugby match. Participation is entirely voluntary and this study will use the 2018 season's game statistics and the results of preseason physical testing. This research will contribute to my Master of Sport and Exercise qualification.

What is the purpose of this research?

The purpose of this study is to examine differences in physical capacities, including anthropometry (body mass and composition), strength, power, sprint performance and aerobic capacity between Rugby Union players who display greater numbers of positive outcomes in tackling and ball carrying (effective, dominant tackles and dominant ball carries) in a match compared to the other players. Very few studies have previously examined the relationship between contact performance and physical fitness. Therefore, the findings of this study may be useful for designing strength and conditioning training programmes to improve contact performance during a match. Furthermore, this research will be a part of Master qualification of Sport and Exercise, and also this will strengthen my future career as a strength and conditioning coach.

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

The primary researcher of this study is a strength and conditioning coach with the Auckland Rugby Union and you are training with this organisation as a representative Rugby Union team member of Auckland. Therefore, you were identified as a potential participant for this research.

The following inclusion criteria will be used for the selection of participants. Players must play longer than 40 minutes per game for data to be analysed and play more than the minimum number of games across the season (5 games for the A side or 4 games for the B side or 4 games for the under 19 side). Furthermore, participants must have completed the preseason physical testing and have at least a six month history of resistance training. Players who do not meet these inclusion criteria will be excluded.

How do I agree to participate in this research?

Participation to this study is voluntary. If you would like to participate in this research, you need to understand the contents of this research, sign the attached *Consent Form*, and return it to Wataru Hiramatsu (the primary researcher).

If you agree to participate in this study, you will give permission for the results of your preseason testing to be used in the analysis. Then the game statistics will be analysed at the end of the 2018 season to define participants as either the high or low level contact performance group.

If you would not like to participate in this research after agreement, you are able to notify me as soon as possible. You may withdraw at any time prior to final data analysis on January 15th 2019.

What will happen in this research?

You will be asked to give permission for the use of your preseason physical testing data that has already been completed and game statistics from the 2018 season. Based on the number of dominant and effective tackles and ball carries, you will be allocated to a high or low contact performance group. The preseason physical testing data will be compared between the two groups of players. The physical testing included 1) body mass and lean body composition, 2) maximum bench press and back squat strength, 3) peak power during the countermovement jump, 4) sprint performance such as acceleration ability and peak running velocity and 5) Yo-Yo intermittent recovery test level 1 distance.

What are the discomforts and risks?

Data obtained will in no way disadvantage or advantage selection into the Auckland Rugby Union's representative team. Voluntary withdrawal from this study will be accepted throughout the entire data collection process with absolutely no adverse consequences.

How will these discomforts and risks be alleviated?

If you would like to refuse to use your data of physical testing and game statistics, you are able to notify the researcher immediately and you will not be included in this study.

What are the benefits?

You will receive information regarding your physical testing data and match contact performance. The findings may be useful for identifying common characteristics in players who are capable of superior contact performance and designing training programmes to improve contact performance during games.

Data collected will also allow me to complete my thesis and gain my Master of Sport and Exercise 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?

The findings of the research may be used in future publications, however the identity and individual results of each participant will be kept confidential. Only my primary supervisor (Prof. Michael McGuigan), and I will have access to, and analyse your results.

What are the costs of participating in this research?

Cost to participate in this study is nil. Time required for this study will be the time for preseason testing, which is approximately three hours.

What opportunity do I have to consider this invitation?

A response to this invitation will be appreciated by no later than the 20th of November 2018.

Will I receive feedback on the results of this research?

Yes, you will. If you would like to, you can inform me and receive a summary of results from this study, once the information is ready (around one month after completing the study). Please check the appropriate box on the *Consent Form* if you would like this information. After the completion of the study, you will receive a summary of this study through email. Additionally, you will also be able to ask the researcher any questions related to results.

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, Prof. Michael McGuigan, michael.mcguigan@aut.ac.nz, or (09) 921 9999 ext 7580

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

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Supervisor, Prof. Mike McGuigan; email: michael.mcguigan@aut.ac.nz or (09) 921 9999 ext 7580

Researcher Contact Details:

Wataru Hiramatsu; email: watarugjg1011@gmail.com or 02102316935

Project Supervisor Contact Details:

Supervisor, Prof. Michael McGuigan; email: michael.mcguigan@aut.ac.nz or (09) 921 9999 ext 7580

Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number*.

Consent Form

Project title: Comparison of physical capacity between high level and low level contact groups in Rugby Union players

Project Supervisor: Professor Michael McGuigan

Researcher: Wataru Hiramatsu

○ I have read and understood the information provided about this research project in the Information Sheet dated 1st September 2018.

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

○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.

○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.

○ I am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any infection.

○ I agree that the results from preseason physical testing by the Auckland Rugby Union as well as 2018 season's game statistics can be used for this research. : Yes○ No○

○ I agree to take part in this research.

○ I wish to receive a summary of the research findings (please tick one). : Yes○ No○

Participant's signature: ....

Participant's name: ....

Participant's Contact Details (if appropriate):

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Date:

Approved by the Auckland University of Technology Ethics Committee on 15 October 2018 AUTEC Reference number 18/333

Note: The Participant should retain a copy of this form.