

TACKLING ABILITY IN RUGBY LEAGUE PLAYERS: A STRENGTH AND CONDITIONING PERSPECTIVE

Submitted by

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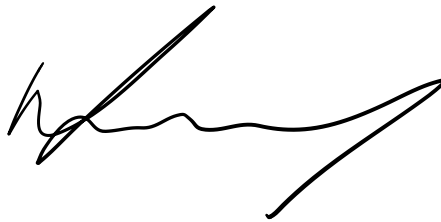
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Declaration

This thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma. No parts of this thesis have been submitted towards the award of any other degree or diploma in any other tertiary institution. No other person's work has been used without appropriate acknowledgement with the thesis. All research procedures reported in the thesis received the approval of the relevant Ethics / Safety Committees (where required).

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Published manuscripts by the Author included in the Thesis

The following experimental studies were completed and published during this PhD and are included as chapters in this thesis.

- 1) Speranza, Michael J. A, Gabbett T. J, Johnston, Rich D, Sheppard, Jeremy M. Muscular strength and power correlates of tackling ability in semi-professional rugby league players. *Journal Strength and Conditioning Research*. 2015; 29(8):2071- 2078. Impact factor: 2.060

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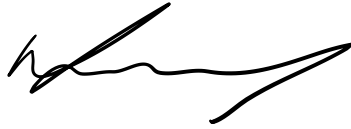
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I hereby declare that my contribution to each of the seven published/submitted manuscripts, as outlined above, to be accurate and true.

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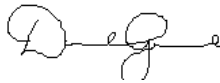
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Abstract

Rugby league is a collision sport that is intermittent in nature, characterised by bouts of high intensity running, collisions and tackling, separated by periods of lower intensity activity. Success in the sport requires a multifaceted skillset with players requiring good ball handling ability, quick and accurate decision making, and the ability to perform effective tackles.

A large part of success in a collision sport such as rugby league is based on player's ability to execute proficient and effective tackles, the ability to dominate the tackle contest, and the capacity to tolerate physical impacts. While the tackle contest is a critical element in rugby league, there is a relatively small body of work investigating this facet of the sport.

It is generally accepted that high levels of muscular strength and power is advantageous for elite rugby league performance as players are required to push, pull, wrestle and tackle their opposition. However, the extent to which strength and power influences specific rugby league skills, such as tackling, is not fully understood.

The aim of this thesis was to examine the influence of muscular strength and power on tackle ability and tackle performance in semi-professional rugby league players. This was achieved through seven experimental studies. The first study examined the muscular strength and power correlates of a standardised one-on-one under-the-ball tackle drill. The second study investigated the influence that changes in muscular strength and power following an 8-week training block had on the aforementioned tackle drill. The third study explored changes in tackle ability during a competitive season and possible relationships with changes in muscular strength and power. Study four examined the relationship

between the standardised one-on-one tackle assessment and match-play tackle performance. Based on the findings of the previous chapter, study five explored the relationships between match-play tackle characteristics, tackle outcomes and physical qualities. The final two studies examined an alternate tackle drill, the over-the-ball tackle drill, and its relationship to strength and power, as well as match-play tackle performance.

It was found that well-developed muscular strength and upper-body power were significantly correlated to tackling ability in rugby league players. Lower body strength as measured by a 1RM squat, maximum squat relative to body mass, and upper body power (plyometric push up) were related to performance in the standardised one-on-one under-the-ball tackle drill. It was also found that over an 8 week period, increases in lower-body strength was related to enhanced tackle ability. Conversely, there was a clear relationship between players who experienced a decrement in lower-body strength and deterioration in tackling ability.

The standardised one-on-one under-the-ball tackle drill was shown to be a reliable (intraclass correlation coefficient for test-retest reliability = 0.88) and valid method to evaluate tackling ability in semi-professional rugby league players. Players with good tackling ability were involved in a greater proportion of dominant tackles and missed fewer tackles during match-play. Lower-body muscular strength was found to be correlated to the proportion of dominant tackles made during match-play. Furthermore, lower-body strength was significantly related to defenders exhibiting a medium body position (tackler presenting moderate flexion at hips and knees) and the ball-carrier being placed on their back. These findings suggest that lower-body strength was related to tackle characteristics and outcomes.

An examination of match-play tackle characteristics found that approximately 70% of tackles were executed around the ball-carriers chest and shoulders and less than 25% of tackles were made at the mid-torso region. Thus, an alternate one-on-one tackle drill was examined where contact was made on the upper-torso of the ball carrier, the over-the-ball tackle. It was observed that upper-body strength and power as measured by plyometric push up peak power was significantly related to over-the-ball tackling ability. Under-the-ball and over-the-ball tackle abilities were shown to be associated with varying indicators of match-play tackle performance. Under-the-ball tackle ability was positively related to the proportion of dominant tackles and negatively related to missed tackles, while over-the-ball tackle ability was positively related to the proportion of dominant tackles and average play-the-ball speeds, and negatively related to tackles that conceded offloads.

Two important findings can be concluded from the studies presented in this thesis. The first is that muscular strength, in particular lower body strength, contributes to under-the-ball tackling ability and match-play tackle outcomes in rugby league players. As long as the technical aspects of tackling technique are adequately coached and practiced, then enhancements in muscular strength and power may be one of the foundational components to underpin improvement in tackling ability.

Secondly, this thesis presented criteria to assess over-the-ball tackling ability, with findings suggesting that the assessment is both valid and reliable. Both the under-the-ball and over-the-ball standardised tackle assessment tests are related to match-play tackle performance indicators, thus justifying the practical utility of these off-field tests to assess tackling ability. Although correlated, this study showed that the two tackle ability tests

were related to different match-play tackle outcomes, indicating that over-the-ball and under-the-ball tackle ability are two different skills and should be assessed and trained accordingly.

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List of Abbreviations

AU	Arbitrary Units
ANOVA	Analysis of variance
CI	Confidence interval
cm	Centimetre
CMJ	Countermovement jump
CV	Coefficient of variation
ES	Effect size
ICC	Intraclass correlation coefficient
kg	Kilogram
min	Minute
m.s ⁻¹	Metres per second (velocity)
NRL	National Rugby League
NYC	National Youth Competition
PPU	Plyometric push-up
RM	Repetition maximum
s	Seconds
SD	Standard deviation
TEM	Typical error of measurement
$\dot{V}O_{2\max}$	Maximal oxygen consumption

Navigation of Thesis

Tackling is arguably one of the most important skills in the sport of rugby league, yet only a relatively small body of research has been conducted in this area. This thesis examines tackling ability in rugby league in four distinct sections.

Chapter 2 provides a critical analysis the current research in the area of tackling in rugby league through a narrative literature review. The primary purpose of this chapter is to provide context of the rugby league tackle contest, present the current research investigating tackling in collision sports and highlight areas yet to be examined.

Chapters 3, 4 and 5 examine the relationship between muscular strength and power qualities and a standardised one-on-one tackling drill. Chapter 3 investigates the strength and power correlates of the tackling ability. Chapter 4 examines the effect of an 8-week resistance training program on tackling ability, while chapter 5 reports on the changes in tackling ability during a competitive season with reference to changes in strength and power qualities.

Chapters 6 and 7 explore the relationships between muscular strength and power, tackling ability and match-play tackle characteristics and performance. There were 3 main aims in these chapters: i) to establish if a standardised one-on-one tackle assessment was related to tackle performance in semi-professional rugby league players ii) to investigate the relationships between strength and power qualities and tackle outcomes iii) to explore how tackle characteristics were related to tackle performance outcomes during rugby league match-play.

The final 2 experimental chapters of this thesis explore the assessment and validity of an alternate standardised tackle drill. The drill examined an over-the-ball tackle style in contrast to an under-the-ball tackle in the previous chapters. Chapter 8 reports on the relationships between the 2 different tackling drills, the strength and power correlates of the 2 drills and compares the assessment in first and second grade players. The final experimental chapter investigates the relationships between over-the-ball tackle ability and tackle performance of players during rugby league match-play.

Chapter 1: General Introduction

Rugby league is a collision team sport played internationally at junior and senior level. The game is intermittent in nature, characterised by bouts of high-intensity running, collisions and tackling separated by periods of lower intensity activity [1-4]. The skillset required for rugby league is multifaceted with players requiring good ball handling ability (e.g. catching, passing and kicking), quick and accurate decision making, and the ability to perform effective tackles [5-7]. Due to the high and contrasting physical demands of the game, rugby league players require well-developed aerobic fitness, speed, muscular strength and power, and agility to compete at an elite level [8]. An understanding of how these physical qualities relate to rugby league performance is essential for the development of effective and specific coaching, as well as relevant strength and conditioning programs.

Rugby league players are subjected to multiple physical collisions throughout a match, most of which occur while players are defending [6]. In defence, players are required to make contact and tackle opposition players to halt their forward progress. The number of tackles that players are required to make is dependent on playing position. Generally forwards will perform an average of 26 tackles, compared to the backs who perform an average of 11 tackles per match [9]. A large part of success in a collision sport such as rugby league is based on tackling proficiency, the capability to dominate the tackle contest, and the capacity to tolerate physical impacts [5]. Previous research investigating tackling technique did so through the analysis of an under-the-ball one-on-one tackling drill. It has been found that this type of tackle technique is strongly associated (negatively) with the proportion of missed tackles and related (positively) to the proportion of dominant tackles that players perform during match-play [10]. Therefore, the ability to

perform a well-executed tackle is integral for the player to be effective in the tackle contest.

1.2 Identifying the Problem

The ability to produce high levels of muscular strength and power is essential for rugby league as players are required to push, pull, wrestle and tackle their opposition [8]. It has been shown that muscular strength and power can discriminate rugby league players of different playing levels. Baker and Newton [11] found that players competing in the national competition were on average 17% stronger and 11.5% more powerful through their lower body than their counterparts competing in a second tier competition. Similarly, it has been found that players who gained selection in a semi-professional team had superior physical qualities, measured by the bench press, squat and vertical jump, than non-selected players [12]. These findings highlight the importance of muscular strength and power for rugby league performance however, the extent to which strength and power influences rugby league skills, such as tackling, is not fully understood.

Several studies have examined the physiological and anthropometric correlates of tackling ability in sub-elite and professional rugby league players [13-16]. Acceleration over a 10-metre sprint and lower body muscular power, measured by a countermovement jump (CMJ) have been shown to be associated with superior under-the-ball tackling ability in elite junior and professional rugby league players [13, 14, 16]. These studies have provided great insight into the physiological factors that impact upon tackling ability however, there are some gaps in current research. Although maximal muscular strength and power have been shown to discriminate between elite and sub-elite rugby league players [11, 17], and muscular strength and power has been shown to be associated with

acceleration [18-20], to date no study has examined the influence of upper- and lower-limb muscular strength on tackling proficiency. Furthermore, no research has examined the effect that changes in strength and power qualities have on tackling proficiency.

Few studies have examined tackle characteristics in rugby league match-play. King et al [21] performed video analysis of tackles in professional rugby league matches by player position, tackle height and tackle location. It involved an analysis of tackles in 80 professional rugby league matches and found that nearly 50% of tackles involved tacklers from behind the visual field of the ball carrier, most tackles involved two or three players, and that the most common site for contact was the hip / thigh region [21]. Austin et al [22] examined tackling in professional rugby league, finding that the first defender involved in a tackle most commonly made a front-on tackle, either low or high. The second player involved was most likely to perform a front-on high tackle with contact made on the upper-torso of the ball-carrier. If a third player was involved in a tackle, generally contact with the player was from the side and above the hips [22]. These studies provide important insights into the tackle contest during rugby league match-play.

However, game-specific tackle performance or its relationship to tackle ability was not examined in either of these studies. Hendricks et al [23] examined the tackler characteristics associated with tackle outcomes in rugby union. The study found that making contact with the legs of the ball carrier, when compared to the mid torso or shoulders, increased the likelihood of a successful tackle however, it also increased the likelihood of an offload [23]. Another study examining contact zones in international rugby union found that winning teams made more waist tackles than leg tackles [24]. While rugby league and union tackles are similar in appearance characteristics associated

with successful performance may differ due to different rules (ie. contested vs non-contested play-the-ball) and tactics. Therefore research examining the association between tackle characteristics and tackle performance in rugby league is required.

To date, all research investigating tackle ability has explored the traditional shoulder tackle, also known as the under-the-ball tackle. The under-the-ball tackle is characterised by the defender making initial contact with their shoulder at the torso region of the ball-carrier. Anecdotally, during match-play there has been increased emphasis on tackles where initial contact is made on the upper-torso of the ball-carrier in order to restrict the promotion of the football (eg. offload) and to affect a slower play-the-ball. Tackles made at the shoulder and chest region are commonly referred to as “over-the-ball” or “smother tackles”. In rugby union match-play it has been reported that the smother tackle was as likely to have successful defensive outcomes in match-play compared to the traditional shoulder tackle [23]. Due to the increased prevalence and the positive performance outcomes associated with an over-the-ball tackle, from a coach’s perspective, it will be useful to examine this type of tackle in a specific drill.

1.3 Aim and Objectives

The overall aim of this thesis was to examine tackling ability in rugby league players and in particular, explore the relationship between tackling ability and muscular strength and power qualities. The specific objectives were to:

1. Examine relationships between under-the-ball tackling ability and muscular strength and power in semi-professional rugby league players.
2. Explore tackle characteristics and outcomes during rugby league match-play and their relationship with tackle ability and physical qualities.

3. Develop an alternate tackle drill to assess over-the-ball tackling ability and examine the relationship with match performance and muscular strength and power characteristics.

The sequence of studies designed to investigate the objectives of thesis were as follows:

TACKLING ABILITY IN RUGBY LEAGUE PLAYERS: A STRENGTH AND CONDITIONING PERSPECTIVE

Relationships Between Tackling Ability and Muscular Strength and Power	Study 1
	Muscular strength and power correlates of tackling ability in semi-professional rugby league players
	Study 2
Tackling Ability and Match-Play Performance	Effect of strength and power training on tackling ability in semi-professional rugby league players
	Study 3
	Changes in rugby league tackling ability during a competitive season: the relationship with strength and power qualities
Alternate Tackle Assessment	Study 4
	Relationship between standardised tackling proficiency test and match-play tackle performance in semi-professional rugby league
	Study 5
	Tackle characteristics and outcomes in match-play rugby league: The relationship with tackle ability and physical qualities
	Study 6
	An alternate test of tackling ability in rugby league players
	Study 7
	Relationship between Two Standardised Tackling Proficiency Tests and Rugby League Match-Play Tackle Performance

Figure 1.1. Sequence of experimental chapters of thesis

Chapter 2: Literature Review

2.1 Rugby League

Rugby league is an intermittent, collision sport played internationally at junior and senior levels. The sport originated from rugby union in the North of England in the late 19th century, hence the reason the two sports have very similar structure, rules and objectives [25]. Rugby league is characterised by bouts of high-intensity activities such as sprinting, collisions and tackling, separated by periods of lower intensity activity. On average, rugby league players will cover between 4000 and 8000 metres, perform approximately 5 to 15 repeated high intensity efforts (defined as three or more maximal acceleration, high speed or contact efforts with less than 21 seconds between each effort) and be subjected to between 24 and 47 collisions, collectively in offence and defence, per game [26]. The wide-ranging physical demands of the sport requires players to have well-developed endurance, speed, agility, strength, and power in order to compete at an elite level [8].

A rugby league team is usually divided into two broad positional groups, forwards and backs. Forwards are further divided into individual playing positions of prop, hooker, second row and lock, while the positions of half-back, five-eighth, centre, winger and fullback make up the backs. Rugby league positional groups have also been divided into three positional categories; hit-up forwards, adjustables and outside backs. The hit-up forwards consist of the props, and second rows; the adjustables include the hooker, halfback, five-eighth and lock, while the outside backs include the fullback, centres, and wingers [22]. The different positions have specific roles and are subjected to varying physical demands. Generally the forwards are involved in significantly more collisions

than backs with hit-up forwards being involved in approximately twice the number of collisions as the other playing positions [9, 16].

While the skillset required for rugby league is multifaceted, tackling is possibly one of the most important skills in the game as success is largely attributed to the ability to perform effective tackles, having a high tolerance for physical impacts, and the capacity to dominate the tackle contest [10]. Additionally, the most frequent rugby league injuries have been shown to occur during the tackle contest [27-30]. Due to its impact on performance and an increased focus on player welfare, there is an increasing amount of research examining the tackle contest in the collision sports of rugby league and rugby union.

2.2 Definition of a Tackle

The international rules of rugby league states that a player in possession is tackled [31]:

- a. When he is held by one or more opposing players and the ball or arm holding the ball comes in contact with the ground.
- b. When he is held by one or more opposing players in such a manner that he can make no further progress and cannot part with the ball.
- c. When being held by an opponent, the tackled player makes it evident that he has succumbed to the tackle and wishes to be released in order to play-the-ball.
- d. When he is lying on the ground and an opponent places a hand on him.

In a study examining tackle characteristics in international rugby union, van Rooyen et al [32] stated that the purpose of a tackle was to “*limit the forward momentum of the ball-*

carrier and to restrict their possession of the ball.” For analytical purposes, Waldron et al [33] defined a successful rugby league tackle as *“when the opposition player in possession of the ball comes in contact with, and is held by, a player under analysis, resulting in the player in possession being unable to make further progress. The end of the tackle is signified by the referee. The ball may be dislodged during this time and the player in contact may be propelled to the floor and ‘held’.”* Furthermore, an unsuccessful tackle was defined as *“when a defending player (under analysis) is deemed to have attempted to make a tackle on an attacking player by making visible and physical contact but fails to execute the actions that constitute a successful tackle. These may be that the attacking player in possession off-loads the ball, the attacking player advances while the tackle attempt is on-going, or the defending players commit a foul during the process of the tackle”* [33]. The definitions provided by Waldron et al [33] provides a comprehensive and succinct summary of successful and unsuccessful tackles and have been adopted for the purposes of this thesis.

2.3 Match-Play Tackles

On average, a team will collectively perform approximately 300 tackles throughout a rugby league match [16, 21]. During the course of a game forwards will perform an average 26.1 tackles, compared to the backs who are involved in 10.7 tackles [9]. In professional rugby league adjustables make the greatest number of tackles, completing 44% of all tackles made in a match, while hit-up forwards are involved in 37% and outside backs the least with 19% [21]. When examining specific playing positions, hookers are involved in the greatest number of tackles in a match, accounting for approximately 15% of tackles, while wingers make up the least completing between 1.7 and 3.3% of tackles [21].

The tackles performed in rugby league can vary by the area of contact on the ball-carrier, the direction of contact (front on, from the side or behind), the type of tackle, and the number of defenders involved in the tackle. Austin et al [22] examined the tackles made by 3 positional groups; hit-up forwards, adjustables and outside backs, over 5 professional rugby league matches. It was found that the hit-up forwards performed most of their tackles as the first player in and making contact front-on and low, this accounted for 22% of the tackles they made. The second most common tackle made by hit-up forwards were front-on and high while being the second player involved (19%). The most common tackle for the adjustables and outside backs was first person in, front-on and high, accounting for 22% and 32% respectively [22]. This data highlights the importance of front-on tackling technique for rugby league players.

King et al [21] classified tackles in professional rugby league matches by playing position and tackle height. The study examined three levels of professional rugby league; International, National Rugby league (NRL) and National Youth Competition (NYC) [21]. It was found that the most common tackle at all three levels involved two tacklers, making up 46% of the total tackles made [21]. The next most common were for three tacklers involved (33%) and only one tackler involved (18%) [21]. The most common contact zone for tackles at international and NYC level was the hip and thigh region, followed by mid torso, lower legs, shoulder and head/neck [21]. However in the NRL competition the most common site for contact was the mid torso [21]. It must be noted that the data presented above was collected during the 2008 competitive season. Given the rapidly evolving coaching tactics used by coaches to gain an advantage these findings may not be a representation of current match-play tackle characteristics.

Currently, no research has examined how tackle characteristics are related to tackle outcomes in rugby league however, it has been conducted in rugby union. Hendricks et al [23] examined the characteristics of successful and unsuccessful tackles in rugby union match-play. The study examined the tackle contests in eighteen professional rugby union matches. It was found that a tackle break was 2.3 times less likely to occur when the tackler had their head up and forward as opposed to having their head in motion [23]. It is thought that by players having their head up and watching the target onto the shoulder improves tackle ability because it allows the tackler to maintain balance and focus on the contact zone [23, 34].

When examining tackle type it was found that a jersey tackle (i.e. a tackle where the tackling players' initial contact with the opposition is by grabbing the jersey), and an arm tackle (i.e. where the tacklers first contact was made with their arms), were 2 to 3 times less likely to have a successful tackle result compared to a shoulder or smother tackle [23]. Furthermore leg drive on contact increased the likelihood of a successful tackle by up to 39% [23].

When examining the contact zone, Hendricks et al [23] found that the likelihood of the ball-carrier breaking a tackle increased by 1.6 times when a leg tackle was attempted as compared to tackles where contact was made at the mid-torso region. This finding is in agreement with another study that found that more successful teams performed a greater proportion of waist tackles to leg tackles than less successful teams [24]. Interestingly, it was found that the most successful tackles were when the defender makes initial contact around the ball-carriers shoulders, when compared to tackles made at the mid-torso or legs [23]. This finding suggests that tackles around the upper-torso of the ball-carrier is

effective in stopping the ball-carriers forward momentum while also preventing the opportunity of an offload.

2.4 Injuries in Rugby League

Due to the multiple collisions that rugby league players engage in during training and matches, some injuries are unavoidable. Numerous studies have reported injury rates of rugby league match-play at varying competition levels [28, 30, 35-40]. Gabbett [40] reported injury rates of 26.8 injuries per 1000 player game hours at the amateur level. Somewhat higher rates have been reported for professional rugby league, with 34 to 52.3 injuries per 1000 player game hours [35-39]. Semi-professional rugby league players are most at risk of injury, with a rate of 67.7 injuries per 1000 player game hours being reported [28]. It was speculated that semi-professional rugby league players are at a greater risk of injury due to a combination of higher levels of fitness and moderate levels of playing skill. This is in contrast to professional rugby league (high fitness and high skill levels) and amateur (low fitness and low skill levels) [35].

The majority of rugby league injuries occur during physical collisions such as tackling or being tackled [27-30]. It has been reported that the tackle contest causes up to 77.2% of all rugby league injuries [27-29]. As tackling is a fundamental component of rugby league, some injuries from collisions are inevitable however, studies have suggested that poor aerobic fitness [30], prolonged high-intensity intermittent running upper-body strength [41], fatigue [25, 42-44], and excessive contact early in the preseason training phase [45] may increase the risk of injury from physical collisions.

Gabbett et al [45] examined collision injuries that occurred during preseason and in-season training sessions. It was reported that injuries from physical contact were more than twice as likely to occur during the preseason phase than in the competition phase [45]. The authors suggested that players were less susceptible to contact injuries in the competition phase than the preseason phase due to improvements in tackling technique and players becoming more conditioned as the season progressed, thereby reducing the risk of fatigue-related injuries [45].

A study examining injuries in professional rugby league found 94% of all rugby league injuries were tackle-related [46]. Tacklers were most likely to be injured when they were performing a one-on-one tackle, making up nearly half (49%) of all tackles that resulted in an injury to the defender [46]. This is a surprising statistic given that one-on-one tackles only make up 18% of all tackles made during match play [21]. Thirty-eight percent of injuries to defending players occurred when initial contact was made at shoulder height on the ball carrying player, while 29% happened when contact was made at the mid-torso region.

Studies investigating injuries in rugby union match-play have suggested that proficient tackle ability may play a role in the prevention or reduction in injury and concussions [47, 48]. Both of these studies assessed tackle proficiency through the retrospective analysis of match-play tackle events [47, 48]. Burger et al [48] found that tacklers displayed poorer tackle technique in events that coincided with the player being injured. Similarly, Hendricks et al [47] concluded that a failure to execute certain criteria during a tackle (i.e. head on the correct side of ball-carrier, use of the shoulder and leg drive upon contact) was related to tackle events in which the defender sustained a concussion. In a study

investigating concussion injuries in professional rugby league it was found that approximately 72% of concussion events were experienced by the defending player [49]. It was found that poor head placement when making the tackle was the most common mechanism for tackle related concussions [49]. Collectively, these studies support that coaches and players focus on improving key technical criteria of tackling to reduce tackle related injuries.

2.5 Tackling Ability

It has been suggested that correct tackle technique may assist in the reduction of injuries in the tackle contest of collision sports [47, 48, 50]. Posthumus and Viljoen [50] described a safe and effective rugby tackle as having the following characteristics:

1. Shorten steps prior to contact
2. Drive forcefully with the shoulder on the same side as the lead leg
3. Contact zone should be in the opponent's trunk
4. The tackler should make initial contact with their shoulder
5. Spine should be in a straight neutral position
6. The tackler's shoulders should be higher than their hips at the time of contact

Studies examining rugby league tackling ability in professional, amateur and junior rugby league players have used very similar criteria when analysing tackle technique in a standardised one-on-one tackle assessment [5, 10, 13, 14, 16, 51]. The following criteria was developed to evaluate tackling ability in rugby league players [5]:

1. Contact is made at the centre of gravity
2. Initial contact is made with the shoulder
3. Contact with opposite shoulder to lead leg
4. Body position square and aligned
5. Arms wrap around the target on contact
6. Leg drive on contact
7. Watch the target onto the shoulder
8. Centre of gravity is forward to the base of support

The aforementioned eight criteria was applied in only one study investigating tackling ability [5]. A follow up study investigating the influence of fatigue on tackling technique used 7 of the 8 criteria, omitting “contacting the target with shoulder” criterion [51]. Subsequent studies by the same author used only 6 of the 8 criteria, with “contacting the target with shoulder” included, and “the opposite shoulder to lead leg” and “arms wrapping around target on contact” criterion omitted [10, 13, 14, 16]. The changes in the testing criteria reflected the changes and development in coaching cues used by the defensive coaches. To evaluate the tackles players were awarded 1 point for each criteria they achieved or 0 points if they failed to meet the criteria while performing a tackle. The players received an aggregate score (arbitrary units) from 6 or 8 tackles, which was then converted to a percentage.

Gabbett and Ryan [10] found the assessment of tackling ability via the aforementioned criteria could discriminate players of different playing levels, finding players competing in the national competition had superior tackling ability compared to players in the second tier competition. Furthermore, it was found that there were significant correlations

between tackling ability and match-play tackle performance outcomes. Tackling technique was significantly related to the proportion of tackles missed ($r = -0.74$), as well as the proportion of dominant tackles made ($r = 0.78$) per game in professional rugby league [10]. Collectively, findings from this study highlight the practical usefulness and validity of the off-field tackle ability assessment.

2.5.1 Correlates of Tackling Ability

Numerous studies have investigated the relationship between tackling ability and physiological and anthropometric qualities, as well as playing level and experience [10, 13, 14, 16, 33].

Physiological

Previous research has examined the physiological correlates of rugby league tackling ability [13, 14, 16]. A study of amateur players, found that better tacklers had superior acceleration over 10 metres and faster change of direction speed [13]. Tackling ability, in professional and elite junior players was also closely associated with acceleration and lower-body muscular power, as estimated from a vertical jump test [13]. No association was found between tackling ability and change of direction speed [14, 16]. From the results of these studies it has been suggested that strength and conditioning coaches should focus on the development of lower-body muscular power and acceleration to assist in the development of tackling ability [16]. To date, no study has examined lower-body muscular strength, or upper-body strength and power as correlates of tackle ability.

Waldron et al [33] examined the relationship between physical characteristics and tackling performance among elite adolescent rugby league players in match-play. This

study differed from previous research examining tackling ability as it examined tackling ability during match-play, and assessed tackle ability on the proportion of successful and unsuccessful tackles completed. The study found no relationship between tackling performance and aerobic power, counter-movement jump (CMJ), or sprint performance, leading the authors to conclude that at an elite adolescent level tackle ability is more reliant on appropriate technique than physical qualities [33].

Anthropometric

Several studies have examined the relationship between anthropometric characteristics and tackling ability over a range of competitive levels [13, 14, 16]. A study examining the tackling ability of junior elite and sub-elite players found that elite players were generally taller, leaner, and heavier than sub-elite players. However, no anthropometric characteristics were associated with tackling ability [14]. This is in contrast to a study examining amateur senior players which reported that several anthropometric characteristics were associated with superior tackling ability [13]. It was found that players with superior tackling ability had lower skinfold thickness, lower body mass, smaller waist and gluteal measurements and less muscle mass, leading the author to suggest that at an amateur level, lean body mass may be advantageous due to the superior power-body mass ratio [13]. Similarly, Gabbett et al [16] found that at a professional and semi-professional level, skinfold thickness was significantly associated (negatively) with tackling ability, however stature and body mass were not.

Playing Level and Experience

Tackling ability improves at higher competitive levels [10, 14, 16]. A study examining rugby league tackling ability in elite and sub-elite players found that elite level players

had superior tackling technique to their less-skilled counterparts [14]. Junior elite players demonstrated leg drive upon contact, watched the target onto their shoulder and kept their centre of gravity forward of their base of support more often than the sub-elite players [14]. Similarly, professional rugby league players exhibited superior tackling ability when compared to semi-professional players [10, 16]. Both studies found that professional rugby league players kept their centre of gravity in front of their base of support, watched the attacking player onto their shoulder and made contact in the target's centre of gravity more often than the semi-professional players.

Playing experience is another variable that influences tackling ability [10, 16]. A study examining elite rugby league players found no significant differences in the tackling ability of players who competed in 0-49, 50-99 or 100-149 national level competition games. However, players who had been involved in more than 150 national level games had significantly better tackling technique [10]. It found that players who had exposure to more than 3-years of elite level specific tackling coaching had superior tackling technique to players who had experienced less than 3-years [10]. Players with more than 3-years of coaching at an elite level made more regular contact with the target's centre of gravity, made initial contact with their shoulder, were able to maintain a square and aligned body position and watched the opponent onto their shoulder [10]. In line with the findings from the aforementioned study, King et al [21] found that players competing in the NYC (players under 20 years of age), missed significantly more tackles than players competing at an International or NRL level.

2.5.2 Fatigue and Tackling Ability

Numerous studies have highlighted that the majority of rugby league injuries occur in the latter stages of the match [29, 37, 40, 46]. King et al [46] found that players were more likely to be injured while making a tackle in the second half of a match compared to the first half. It has also been found that sub-elite players with relatively low levels of aerobic fitness were at a heightened risk of a tackle related injury [30]. The authors suggest that fatigue and or low fitness levels may be associated with a decrement in tackling technique thus increasing risk to tackle related injuries.

Gabbett et al [51] examined the effect of fatigue on tackle technique in sub-elite rugby league players. The study involved the video analysis of a standardised one-on-one tackling drill in a non-fatigued state and again following a sport specific repeated-effort protocol to simulate fatigue similar to that of match-play. The study also measured physiological characteristics including sprint ability, agility, muscular power, and estimated maximal aerobic capacity ($\dot{V}O_{2max}$). It was found that increased fatigue resulted in a reduction in tackling ability. Additionally, the study found that there was a significant relationship between estimated $\dot{V}O_{2max}$ ($r = -0.62$) and agility ($r = 0.68$) and a reduction in tackling ability while in a fatigued state [51]. Furthermore, players who demonstrated the greatest tackling ability in a non-fatigued state had the largest decrement in tackling ability while fatigued [51]. It was concluded that players with effective tackling ability while in a non-fatigued state may not necessarily be as effective when under fatigue, and that well-developed physical qualities (specifically estimated $\dot{V}O_{2max}$ and agility) were protective against fatigue-induced reductions in tackling ability [51].

2.5.3 Changes in Tackling Technique with Training

Although tackling is a fundamental skill in rugby league there is very limited research into the effect that training and coaching has on tackling performance. Only one study has examined the influence of specific coaching on tackling technique [10]. Gabbett and Ryan [10] found that there was a small, but not statistically significant, improvement in tackling technique following a 3-month skills training program in professional rugby league players. The authors found that the greatest improvements in tackling technique occurred in the players with the lowest initial tackling technique [10]. Following the 3-month training program players more frequently made initial contact with their shoulder, made contact with the target in the centre of mass, and kept their centre of gravity in front of their base of support [10]. A major limitation for this study however, was the small sample size, with only 8 players examined.

2.6 Muscular Strength and Power Characteristics and Rugby League Players

The relationship between muscular strength and power, and rugby league playing ability has been extensively examined [11, 12, 17, 52-55]. Baker and Newton [11] examined lower body strength in rugby league players of different playing levels. This study found that lower body strength and power could discriminate players of different playing level. Players who competed in the national competition were 17% stronger, as assessed by a 1RM squat, and 11.5% more powerful in a Smith machine jump squat, than players competing in the lower state level competition [11]. Interestingly, a similar study examining the differences in strength and power in different levels of rugby union competition found that there was no significant difference in lower-body strength between professional and semi-professional players, although the professional rugby players had superior lower-body power output [56].

Research has also shown that upper-body muscular strength and power can discriminate rugby league players of different playing levels [17]. Baker [17] found that national level players had greater upper-body maximal and relative strength and power than elite college or high school aged players. Argus et al [56] showed professional rugby union players had significantly better upper-body strength than their college and high school aged counterparts. When upper-body strength was compared between professional and semi-professional rugby players, the professionals had significantly better maximal strength and power, but there were only trivial differences in their relative strength [56].

The influence that strength and power qualities have on team selection has been examined in a number of studies [12, 52, 57, 58]. At a junior level, elite players have been shown to have superior lower-body power than sub-elite players [58]. However, there was no significant difference in power between players who made team selection (i.e. starters) and those who did not (i.e. non-starters) [58]. These results are in partial agreement with others who found that players selected to a professional rugby league team had superior vertical jump performance to non-selected players [57]. A study of a semi-professional team found that the physiological capacities of the players did not influence their selection or non-selection for the team [52]. Similar results were found with rugby league team selection at an amateur level [54]. The authors suggested that at amateur and semi-professional level, player selection was based more on body mass, experience and skill than physical qualities [52]. A more recent study found that players who were selected to a semi-professional team had superior maximal bench press repetitions at body mass, 3RM squat, 3RM chin up, and vertical jump performance than the non-selected players [12].

Acceleration and maximum speed qualities of rugby league players have been examined in numerous studies [11, 15, 52, 54, 57, 58]. At a semi-professional level, sprint ability over a variety of distances was not significantly different between the first or second grade teams, with the author suggesting that skill rather than physiological qualities discriminated playing level at a semi-professional level [52]. Conversely, Gabbett et al [58] found that junior elite players were significantly quicker over 10, 20 and 40 metres than their junior sub-elite counterparts. Similarly, players who were selected to compete in a professional national level team were significantly faster over 10 and 40 metres than non-selected players [57]. This is in contrast to the Baker and Newton [11] study that found no significant differences between 10 and 40 metre sprint times in national and state level players. However, the authors concluded that sprint momentum, the product of 10 metre velocity and body mass, was better at discriminating between the two playing levels [11].

2.7 Skill Development

It has been suggested that in most fields (e.g., music, chess, sport), attainment of the highest level of performance and expertise requires individuals to be exposed to approximately 10 years or 10,000 hours of experience [59-62]. However, it has been found that the number of years of exposure and experience in a specific domain is only weakly related to performance [60]. Ericsson et al [60] concluded that the acquisition of expert skills and performance requires more than experience but rather 10 years engaged in deliberate practice. Deliberate practice is described as “*individualized training activities especially designed by a coach or teacher to improve specific aspects of an individual’s performance through repetition and successive refinement*” [63].

The theory of deliberate practice was originated from studies examining musical proficiency however, it appears that the theory holds true in a team sport setting [61]. Studies examining soccer and hockey players found that accumulated training hours was the key factor discriminating players competing at an international, national or provincial level [61]. The authors noted that unlike music, where the skill is very specific, the requirements for team sports performance is multifaceted; individuals need to develop specific fitness, strength and power qualities, sport specific skills and strategies; therefore a wide range of activities, such as resistance training, video analysis, and playing other sports should be considered as forms of deliberate practice [61].

In terms of rugby league tackling ability, players with greater than 150 national games experience had significantly superior tackling ability compared to players with less than 150 games [10]. In line with the theory of deliberate practice, players who had received 3 or more years of specific coaching based on fundamental technical criteria had significantly better tackling [10]. The NRL season consists of 24 fixture matches, as well as finals, and possible representative games, therefore this study suggested that high-performance players require a minimum of 5 years exposure at an NRL level for significant improvements in tackling ability to be observed [10].

2.7.1 Influence of Muscular Strength and Power on Sport Specific Skills

Theoretically, superior levels of muscular strength and power are beneficial for the performance of dynamic sport specific skills. Several studies support the theory that strength and power are some of the underlying qualities for enhanced athletic performance. Judge et al [64, 65] established that maximal back squat, power clean and bench press were related to track and field throwing performance in college and elite level

athletes. In a study examining punching power in national level boxers Loturco et al [66] concluded that stronger athletes outperformed weaker athletes. Gorostiaga et al [67] found that stronger handball athletes were able to produce faster throwing velocities compared to their weaker counterparts. Numerous other studies investigating track cycling, weightlifting and track sprinting have reported similar findings [68-70]. Collectively these studies highlight that muscular strength and power has some influence in the performance of sport specific skills.

It has been established that high levels of muscular strength and power are related to sporting ability and successful performance however, research suggests that an increase in strength and power does not automatically transfer to improvements in motor skill [71-73]. Morris et al. [71] examined the influence of a six-week isokinetic knee extension and flexion strength program on standing long jump performance. Although there was significant improvements in leg strength, the improvements in long jump performance were non-significant [71]. The authors suggested that the lack of improvement in jumping performance may be due to the training stimulus being non-specific to the testing protocol [71]. Similarly, Mayhew et al [73] found that a 12 week heavy bench press training intervention significantly improved 1RM bench press (9.1%) and bench press power (13.6%) however, the increase in strength and power did not translate to a significant improvement in a seated shot put task. Sale and MacDougall [74] proposed that a training stimulus must reflect the movement pattern, contraction type, contraction force and contraction velocity for there to be a meaningful transfer effect from the training stimulus.

Conversely, a study of amateur soccer players found that a 10-week resistance training program that increased muscular strength, also transferred into significant improvements

in kicking performance [75]. It was concluded that enhanced kicking performance was accompanied by improvements in lower limb maximal strength and altered kick biomechanics [75]. The kicking pattern of players changed due to an increase in maximal knee angular velocity and maximal ankle linear velocity during the forward phase of the swing, as well as increased muscle activation during the kicking phase [75].

2.8 Conclusion

The review of the literature reveals that tackle technique is critical from a performance perspective as well as an injury prevention / reduction perspective. A standardised one-on-one tackle assessment discriminates between performance levels and is significantly related to on-field tackle outcomes. Previous research has found that a number of physical qualities are associated with tackling ability [13, 14, 16] and it was proposed that if an appropriate amount of time was devoted to the skill of tackling, then improvements in these physical qualities may transfer to improvements in tackling ability. Although well-developed muscular strength and power qualities are related to elite performance in rugby league no research has examined the association between muscular strength and tackling ability.

The current research conducted on rugby league match-play has focused on the description of tackles. Although these studies provide a good description of the most common tackle characteristics in rugby league match-play, no research has attempted to identify how these characteristics influence tackle outcomes such as successful, missed, or dominant tackles.

An increasing body of research has examined tackling ability in rugby league players through video analysis of a standardised one-on-one tackling drill. These studies

investigated tackle ability through the assessment of the traditional shoulder tackle, also known as the under-the-ball tackle. The under-the-ball tackle is characterised by the defender making initial contact with their shoulder at the torso region of the ball-carrier. Anecdotally, there has been an increased focus on defenders making contact on the upper-torso of the ball carrier, commonly known as an over-the-ball tackle or smother tackle. A player's ability to perform a traditional shoulder tackle may not reflect their ability to tackle over-the-ball. No research to date has examined an alternate tackle assessment that is representative of the over-the-ball tackle.

2.9 Aim and Objectives

The overall aim of this thesis was to examine tackling ability in rugby league players and in particular, explore the relationship between tackling ability and muscular strength and power qualities. The specific objectives were to:

1. Examine relationships between under-the-ball tackling ability and muscular strength and power in semi-professional rugby league players.
2. Explore tackle characteristics and outcomes during rugby league match-play and their relationship with tackle ability and physical qualities.
3. Develop an alternate tackle drill to assess over-the-ball tackling ability and examine the relationship with match performance and muscular strength and power characteristics.

Chapter 3: Muscular Strength and Power Correlates of Tackling Ability in Semi-Professional Rugby League Players

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3.1 Abstract

This study investigated the relationship between muscular strength and power and tackling ability in semi-professional rugby league players. Thirty-six semi-professional (mean \pm SD age, 23.1 ± 3.6 years) rugby league players, from three distinct playing divisions (first grade, second grade, and Under 20's), underwent tests of upper-body strength (3 repetition maximum [RM] bench press), lower-body strength (3RM squat), upper-body power (plyometric push-up) and lower-body power (countermovement jump). Muscular strength relative to body mass was also calculated. Tackling ability of the players was tested using video analysis of a standardised one-on-one tackling drill. For all players, the strongest correlates of tackling ability were squat ($r = 0.67$), bench press ($r = 0.58$), relative squat ($r = 0.41$), and plyometric push-up ($r = 0.56$). The strongest correlates of tackling ability in first grade players was squat ($r = 0.72$), bench press ($r = 0.72$), relative squat ($r = 0.86$), and plyometric push-up ($r = 0.70$). For second grade players only relative squat ($r = 0.60$) and plyometric push-up ($r = 0.67$) were associated with tackling ability. The strongest correlates of tackling ability in Under 20's players were squat ($r = 0.77$), bench press ($r = 0.70$), and plyometric push-up ($r = 0.65$). The findings of this study demonstrate that muscular strength and upper-body power contribute to tackling ability in semi-professional rugby league players. Therefore, as long as the technical aspects of tackling technique are adequately coached and practiced, then enhancements in muscular strength and power may serve as foundational components to underpin improvement in tackling ability.

3.2 Introduction

Rugby league is a collision sport played internationally at junior and senior level. The game is intermittent in nature, characterized by bouts of high intensity running, collisions and tackling, separated by periods of lower intensity activity [3, 4]. The skillset required for rugby league is multifaceted with players requiring good ball handling ability (e.g. catching, passing and kicking), quick and accurate decision making, and the ability to perform effective tackles [57]. Rugby league players require well-developed aerobic fitness, speed, muscular strength and power, and agility to compete at an elite level [8]. An understanding of how these physical qualities relate to specific rugby league skills is essential for the production of specific coaching, and strength and conditioning programs.

Rugby league players are subjected to multiple physical collisions throughout a match, most of which occur while players are defending [2, 6]. In defense, players are required to make contact and tackle opposition players to halt their forward progress. The number of tackles that players are required to make is dependent on playing position [76]. Generally forwards will perform an average of 39 tackles, compared to the backs who perform an average of 16 tackles per match [76]. A large part of success in a collision sport such as rugby league is based on tackling ability, the capacity to dominate the tackle contest, and the ability to tolerate physical impacts [5]. Tackling technique as examined by a one-on-one tackling drill has been found to be strongly associated with the proportion of missed tackles (negative) and the proportion of dominant tackles (positive) that players complete during match-play [10]. Therefore, the ability to perform a well-executed tackle is critical for the player to “win” the contact contest.

The majority of rugby league injuries occur during physical collisions and tackles [28, 35]. Studies have shown that up to 77.2% of all injuries occur during tackles, with 40% of these injuries occurring to the player performing the tackle [27-29, 35]. It has been proposed that poor tackling technique may be a significant risk factor for injury [34, 50], however there is limited evidence to support this claim [77]. In the interest of injury prevention, authors have suggested that improving tackling technique may decrease the likelihood of injury while making a tackle [40, 78].

Several studies have examined the physiological and anthropometric correlates of tackling ability in sub-elite and professional rugby league players [13, 14, 16]. Well-developed acceleration (over a 10-metre sprint) and lower-body muscular power are associated with superior tackling ability in elite junior and professional rugby league players [13, 14, 16]. These studies have provided great insight into the physiological factors that impact upon tackling ability, however there are some gaps in current research. Although maximal muscular strength and power have been shown to discriminate between elite and sub-elite rugby league players [11, 17], and muscular strength and power are associated with acceleration [18-20], to date no study has examined the influence of upper and lower limb muscular strength on tackling performance. Furthermore, no study has examined the physiological correlates of tackling ability in semi-professional rugby league players. With this in mind, the purpose of this study was to examine the tackling ability of semi-professional rugby league players and investigate the relationship between muscular strength and power qualities and tackling ability in these players.

3.3 Methods

Experimental Approach to the Problem

In order to test our hypothesis, a cross-sectional experimental design was used to compare muscular strength and power qualities as well as tackling ability in first grade, second grade, and under 20's players. Pearson's product-moment correlation coefficients were used to determine the relationship between the independent variables (i.e. muscular strength and power), and the dependant variable (i.e. tackling ability). It was hypothesized that players with superior upper- and lower-body muscular strength and power would have more effective tackling technique.

Subjects

Thirty-six rugby league players (mean \pm SD age, 23.1 ± 3.6 years) participated in this study. All players were from one of three teams in the same rugby league club; first grade players ($n = 10$) competed in a state level competition, second grade players ($n = 12$) competed in a metropolitan competition, and under 20's players ($n = 14$), who were under 20 years of age and competed in a metropolitan competition. Players were classified as semi-professional as they received remuneration for playing rugby league but also relied on other forms of income. Players were free from injury and mid-way through a fifteen-week preseason training program when they undertook muscular strength and power testing, and the tackling assessment. All players received a detailed explanation of the study, including information on the risks and benefits. Written, informed consent was obtained before the start of the study. The players were free to withdraw from the study at any time. All the procedures for this study were preapproved by the Australian Catholic University Ethics Reviewing Panel.

Muscular Strength

Upper- and lower-body muscular strength was assessed using a three-repetition maximum (3RM) bench press and squat test, respectively. The players were familiar with the tests as they were part of routine testing. The tests were conducted 72 hours after the previous session and players were instructed to refrain from excessive exercise prior to the testing session. The testing occurred in the evening. Players were instructed to maintain their normal diet and hydration as they would for normal training sessions. For the 3RM test the players were instructed to perform progressively heavier loads, with 3 to 5 minutes rest between sets, until they attempted a load that they could lift for a maximum of three full range repetitions. A strength and conditioning specialist familiar with the players supervised and guided the players to perform the squats to below parallel. The intraclass correlation coefficients for test-retest reliability and typical error of measurement were 0.96 and 2.6% for the 3RM bench press and, 0.91 and 3.6% for the 3RM squat. Relative upper- and lower-body strength were calculated by dividing the 3RM of the bench press and squat by the player's body mass.

Muscular Power

Lower- and upper-body peak power was assessed with the players performing a countermovement jump (CMJ) and plyometric push-up on a force platform with a sampling rate of 500 Hz (Kistler 9290AD Force Platform, Kistler, Switzerland). To perform the CMJ, players were required to keep their hands on their hips for the duration of the movement. When instructed, the players dipped to a self-selected depth before explosively jumping as high as possible. Players had two attempts with their highest power output recorded. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for CMJ peak power were 0.81 and 3.5% respectively. For

the plyometric push-up, the players were instructed to place their hands on the force platform while in the push-up position with their arms at full extension. When indicated, the players lowered their body before performing an explosive push-up that caused their hands to leave the platform. The players had two attempts with their highest power output recorded. All testing occurred at the start of a regular training session to limit fatigue related interference. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for the plyometric push-up were 0.97 and 3.8% respectively.

Tackling Technique

The protocol used to examine tackling ability through the video analysis of a standardised 1-on-1 defensive drill was the same used in previous studies [13, 14, 16]. The drill was conducted in a 10 metre grid with video cameras (Canon Legria HV40, Japan) on the left, right and rear of the drill. The drill required the participant to tackle a participant carrying a ball of similar height and mass. The ball carrying participant was required to run directly at the tackling participant and take no evasive action. The participants performed six consecutive tackles, three on the right shoulder and three on the left shoulder. The drill was performed 48-hours after the strength and power testing and at the start of a training session so that the participants were in a non-fatigued state. Tackling technique was assessed by a sport scientist using standardised technical criteria that has been used in previous studies of tackling technique in rugby league players [13, 14, 16].

The technical criteria included:

1. Contact made at the centre of gravity
2. Initial contact made with the shoulder
3. Body position square and aligned

4. Leg drive on contact
5. Watch the target onto the shoulder
6. Centre of gravity forward of the base of support

Each tackle received a score out of 6 (arbitrary units). Players were awarded 1 point for each criteria they achieved or 0 points if they failed to meet the criteria while performing a tackle. The players received an aggregate score (arbitrary units) from all 6 tackles, which was then converted to a percentage. Movement velocity immediately prior to contact was calculated using video analysis (Silicon Coach, New Zealand). The intraclass correlation coefficient for test-retest reliability and typical error of measurement for tackling technique were 0.88 and 3.9%, respectively. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the movement velocity were 0.94 and 2.9%, respectively.

Statistical Analyses

Data were tested for normality using a Shapiro-Wilk test. Analysis of variance (ANOVA) with post hoc testing (Tukey) was used to establish statistical differences in the muscular strength and power, and tackling ability among the different playing levels. Differences in physiological variables and tackling ability between the three different playing levels were also compared using Cohen's effect size (ES) statistic [79]. Effect sizes of <0.2, 0.2-0.6, 0.61-1.2, 1.21-2.0, and >2.0 were considered trivial, small, moderate, large, and very large, respectively [80]. Pearson product moment correlation coefficients were used to determine the relationships among muscular strength and power, and tackling ability. The level of significance was set at $p \leq 0.05$.

3.4 Results

Strength and Power Qualities

The raw data (means \pm SD), along with magnitudes of the differences between the muscular strength and power of the three playing groups are presented in table 3.1. While no significant differences in muscular strength and power were found between the three playing levels, small to moderate differences were found between first and second grade players ($p = 0.18$; ES = 0.22) and first grade and under 20 players ($p = 0.08$; ES = 1.02) for upper body strength. The first grade players demonstrated greater lower-body strength than the second grade ($p = 0.51$; ES = 0.49) and under 20's players ($p = 0.72$; ES = 0.31); there was a trivial difference between the under 20's and second grade team ($p = 0.92$; ES = -0.16). First grade players had better bench press relative to their body mass than second grade ($p = 0.73$; ES 0.32) and under 20's ($p = 0.37$; ES = 0.80); there was a small difference between second grade and under 20's ($p = 0.82$; ES = 0.20). A trivial difference was found between the first grade and the under 20's ($p = 0.98$; ES= 0.03) for relative squat, however a small difference was found for both grades when compared to the second grade team. Trivial to small differences were found among playing groups for CMJ and plyometric push-up.

Table 3.1 Tackling ability, and muscular strength and power characteristics of semi-professional rugby league players. †

	<u>Effect Size</u>					
	First Grade	Second Grade	Under 20's	First Grade v Second Grade	First Grade v Under 20's	Second Grade v Under 20's
Body Mass (kg)	91.5 ± 9.9	93.4 ± 9.1	88.1 ± 10.1	-0.19	0.34	0.55
Squat (kg)	132.5 ± 19.0	123.8 ± 16.0	126.6 ± 19.4	0.49	0.31	-0.16
Bench (kg)	117.5 ± 11.61	114.9 ± 14.69	105.4 ± 12.32	0.22	1.02	0.68
Relative Squat (kg·kg ⁻¹)	1.44 ± 0.09	1.33 ± 0.20	1.44 ± 0.18	0.56	0.03	-0.55
Relative Bench (kg·kg ⁻¹)	1.30 ± 0.09	1.24 ± 0.21	1.20 ± 0.15	0.32	0.80	0.20
CMJ Peak Power (W)	4861 ± 1031	4635 ± 541	4515 ± 514	0.27	0.40	0.23
PPU Peak Power (W)	1519 ± 480	1472 ± 307	1468 ± 279	0.11	0.13	0.20
Velocity (m·s ⁻¹)	3.30 ± 0.76	3.44 ± 0.43	2.90 ± 0.58	-0.22	0.58	1.07
Tackling Ability (%)	76.1 ± 8.6	69.4 ± 7.9	62.7 ± 17.8	0.80	1.02	0.50

Squat = 3RM squat; 3RM bench press; CMJ = counter movement jump; PPU = plyometric push up; Velocity = velocity prior to contact.

† Data are means ± SD. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

Tackling Ability

Tackling ability and velocity prior to contact of the three playing groups are shown in Table 3.1. The first grade players had superior (although non-significant) tackling ability compared to the second grade ($p = 0.50$; $ES = 0.80$) and under 20's ($p = 0.06$; $ES = 1.02$) players. There was also a small difference in tackling ability between second grade and under 20's ($p = 0.42$; $ES = 0.55$) players. The first and second grade players produced greater velocity at the point of contact than the under 20's players with the magnitudes of difference being small ($p = 0.25$; $ES = 0.58$) and moderate ($p = 0.24$; $ES = 1.07$), respectively. The average velocity prior to contact was higher in second grade players than first grade players with a small difference ($p = 0.26$; $ES = -0.22$) found.

Relationship between Strength and Power Qualities and Tackling Ability

Tables 3.2-3.5 outline the relationships between strength and power qualities and tackling ability. Among all the players the strongest correlates of tackling ability were 3RM squat ($r = 0.67$, $p < 0.01$), 3RM bench press ($r = 0.58$, $p < 0.01$), relative squat ($r = 0.41$, $p = 0.01$), and plyometric push-up ($r = 0.56$, $p < 0.01$). The strongest correlates of tackling ability in first grade players were 3RM squat ($r = 0.72$, $p = 0.02$), 3RM bench press ($r = 0.72$, $p = 0.02$), relative squat ($r = 0.86$, $p < 0.01$), and plyometric push-up ($r = 0.70$, $p = 0.03$). For second grade players, only relative squat ($r = 0.60$, $p = 0.04$), and plyometric push-up ($r = 0.67$, $p = 0.02$) were associated with tackling ability. The strongest correlates of tackling ability in under 20's players were 3RM squat ($r = 0.77$, $p < 0.01$), 3RM bench press ($r = 0.70$, $p < 0.01$), and plyometric push-up ($r = 0.65$, $p = 0.01$).

Table 3.2. Relationship among physiological characteristics and tackling ability in semi-professional rugby league players. †

	Body Mass	Squat	Bench	Rel Squat	Rel Bench	CMJ	PPU	Velocity	Tackle
Body Mass	1.00								
Squat	0.55**	1.00							
Bench	0.45**	0.57**	1.00						
Rel Squat	-0.26	0.67**	0.26	1.00					
Rel Bench	-0.44**	0.08	0.60**	0.49**	1.00				
CMJ	0.46**	0.44**	0.30	0.11	-0.10	1.00			
PPU	0.35*	0.56**	0.43**	0.33*	0.09	0.03	1.00		
Velocity	-0.02	-0.07	0.16	-0.07	0.17	0.25	0.11	1.00	
Tackle	0.39*	0.67**	0.58**	0.41*	0.23	0.25	0.56**	0.26	1.00

Squat = 3RM squat; 3RM bench press; Rel Squat = squat relative to body mass; Rel Bench = bench press relative to body mass; CMJ = counter movement jump peak power; PPU = plyometric push up peak power; Velocity = velocity prior to contact; Tackle = tackling ability.

† Data are reported as Pearson product-moment correlation coefficients, r.

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

Table 3.3. Relationship among physiological characteristics and tackling ability in First Grade semi-professional rugby league players. †

	Body Mass	Squat	Bench	Rel Squat	Rel Bench	CMJ	PPU	Velocity	Tackle
Body Mass	1.00								
Squat	0.91**	1.00							
Bench	0.77**	0.77**	1.00						
Rel Squat	0.42	0.76*	0.50	1.00					
Rel Bench	-0.48	-0.34	0.19	0.03	1.00				
CMJ	0.57	0.57	0.35	0.38	-0.38	1.00			
PPU	0.69*	0.73*	0.79**	0.51	0.02	0.02	1.00		
Velocity	-0.20	0.07	0.23	0.50	0.60	0.11	0.21	1.00	
Tackle	0.46	0.72*	0.72*	0.86**	0.27	0.20	0.70*	0.60	1.00

Squat = 3RM squat; 3RM bench press; Rel Squat = squat relative to body mass; Rel Bench = bench press relative to body mass; CMJ = counter movement jump peak power; PPU = plyometric push up peak power; Velocity = velocity prior to contact; Tackle = tackling ability.

† Data are reported as Pearson product-moment correlation coefficients, r.

* Significant at p<0.05.

** Significant at p<0.01.

Table 3.4. Relationship among physiological characteristics and tackling ability in Second Grade semi-professional rugby league players. †

	Body Mass	Squat	Bench	Rel Squat	Rel Bench	CMJ	PPU	Velocity	Tackle
Body Mass	1.00								
Squat	0.16	1.00							
Bench	-0.02	0.24	1.00						
Rel Squat	-0.52	0.75**	0.25	1.00					
Rel Bench	-0.59*	0.12	0.81**	0.52	1.00				
CMJ	0.29	0.35	0.08	0.10	-0.09	1.00			
PPU	-0.47	0.34	0.07	0.59*	0.30	-0.35	1.00		
Velocity	0.00	0.04	0.17	0.03	0.08	0.46	0.10	1.00	
Tackle	-0.16	0.55	0.18	0.60*	0.26	-0.27	0.67*	0.16	1.00

Squat = 3RM squat; 3RM bench press; Rel Squat = squat relative to body mass; Rel Bench = bench press relative to body mass; CMJ = counter movement jump peak power; PPU = plyometric push up peak power; Velocity = velocity prior to contact; Tackle = tackling ability.

† Data are reported as Pearson product-moment correlation coefficients, r.

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

Table 3.5. Relationship among physiological characteristics and tackling ability in under 20's semi-professional rugby league players. †

	Body Mass	Squat	Bench	Rel Squat	Rel Bench	CMJ	PPU	Velocity	Tackle
Body Mass	1.00								
Squat	0.63*	1.00							
Bench	0.59*	0.83**	1.00						
Rel Squat	-0.19	0.64*	0.44	1.00					
Rel Bench	-0.50	0.17	0.40	0.67**	1.00				
CMJ	0.49	0.36	0.35	-0.02	-0.15	1.00			
PPU	0.68**	0.59*	0.55*	0.09	-0.18	0.38	1.00		
Velocity	-0.11	-0.25	-0.24	-0.22	-0.11	0.30	-0.05	1.00	
Tackle	0.59*	0.77**	0.70**	0.38	0.08	0.49	0.65*	-0.00	1.00

Squat = 3RM squat; 3RM bench press; Rel Squat = squat relative to body mass; Rel Bench = bench press relative to body mass; CMJ = counter movement jump peak power; PPU = plyometric push up peak power; Velocity = velocity prior to contact; Tackle = tackling ability.

† Data are reported as Pearson product-moment correlation coefficients, r.

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

3.5 Discussion

This study is the first to examine the strength and power correlates of tackling in semi-professional rugby league players. It is also the first study to investigate the relationship between muscular strength qualities and rugby league tackling ability. The results from this study demonstrate that players competing at a higher competitive standard have superior tackling ability and, in general, the strongest correlates of tackling ability were maximal squat, maximal bench press, relative squat and plyometric push-up. These findings demonstrate that well-developed muscular strength and upper-body power contribute to tackling ability in semi-professional rugby league players.

As expected, the first grade squad demonstrated superior tackling technique when compared to the second grade team, who in turn had superior tackling ability to the under 20's players. The results of this study are consistent with other studies, which have shown that tackling ability can discriminate rugby league players of different playing levels [14, 16]. Two previous studies found moderate to large differences ($ES = 1.10-1.53$) in tackling ability between professional and semi-professional players [10, 16]. Similarly, a study examining junior rugby league players found that elite players had greater tackling ability ($ES = 0.82$) than their sub-elite counterparts [10, 14]. The combined results of these studies suggest that tackling ability improves as the competitive standard increases.

This is the first study to examine the relationship between maximal strength and tackling ability. As hypothesized, lower- and upper-body strength were shown to be closely associated with tackling ability in semi-professional rugby league players. The strongest muscular strength correlates of tackling ability in the first grade squad were squat, bench press, and relative squat. Maximal squat and bench press were also associated with

tackling ability in the under 20's squad, however relative squat was not significantly related to tackling ability. The only strength quality that was significantly related to tackling ability in the second grade team was relative squat. A possible explanation for the lack of association between maximal squat and bench press and tackling ability in the second grade players may be due to the standard of these players. Gabbett [52] concluded that at lower playing levels, physiological capacities of players did not influence their selection or non-selection, suggesting that at an amateur or sub-elite level, team selection was based more on body mass, playing experience and skill. Despite this, these results highlight the significance of muscular strength qualities for effective tackling technique in rugby league.

The plyometric push-up was the only muscular power quality that was associated with tackling ability in all three grades, suggesting that upper-body power is significant to tackling ability independent of playing standard. These results are in contrast to previous research. Gabbett [13] examined correlates of tackling ability in sub-elite rugby league players and used an overhead medicine ball throw to determine upper-body power and found there was no significant relationship between upper-body power and tackling ability. This discrepancy may be due to the different movement patterns used in the two tests. An overhead throwing movement is not very common in rugby league therefore may not be as specific as the plyometric push-up which replicates fending and pushing opponents which are fundamental actions in rugby league [81]. Furthermore, the reliability of an overhead medicine ball throw has been shown to be affected by the weight of the ball thrown and throwing technique [82]. The plyometric push-up test on a force platform has been shown to be a reliable protocol for measuring upper-body strength in rugby league players [83].

This study found that lower-body power, as measured by the CMJ was not significantly related to tackling ability. This finding is in agreement with a previous study that found vertical jump performance was not significantly associated with tackling ability in sub-elite rugby league players [58]. However it is in conflict with other studies that found a significant association between vertical jump performance and tackling ability in professional and elite junior rugby league players [14, 16]. A possible reason for the lack of relationship between CMJ and tackling ability may be due to the lack of movement specificity of the test for lower-body power. A large component of tackling ability is the ability to produce high levels of horizontal leg drive to halt the forward progress of the attacking player. Maulder and Cronin [84] found that horizontal jump tests have stronger relationships to sprint ability than vertical jump tests with the authors suggesting that their finding was due to the horizontal nature of sprinting which is not assessed by vertical jumping. Future studies should examine the relationship between horizontal leg power and tackling ability.

The strongest correlates of tackling ability were squat ($r = 0.67$), bench press ($r = 0.58$), relative squat ($r = 0.41$), and plyometric push-up ($r = 0.56$). The coefficient of determination (r^2) for these strength and power qualities ranged between 17% and 45%. Therefore, 55% to 83% of the variance in tackling ability is explained by factors in addition to, or other than muscular strength and power characteristics. While this study provides an important step in explaining the influence that muscular strength and power has on tackling ability, it must be acknowledged that additional factors (e.g. technical factors, experience) may explain a greater proportion of this skill.

The standardised one-on-one tackling drill has been shown to be significantly related to the proportion of missed tackles ($r = -0.74$) and the proportion of dominant tackles ($r = 0.78$) in professional rugby league match-play [10]. To date, no study has examined how the standardised one-on-one tackling drill is related to match performance at a semi-professional level, providing scope for future research.

In conclusion, this is the first study to examine the relationship between physiological qualities and tackling ability in semi-professional rugby league players. It is also the first study to examine the influence that muscular strength and power has on tackling ability. These findings demonstrate that muscular strength and upper-body power contribute to tackling ability in semi-professional rugby league players. Further research examining the relationship of muscular strength and power on tackling ability in other competitive levels, such as professional and junior players, is warranted. Although this study has identified a number of physiological qualities associated with tackling ability, the results do not imply cause and effect. Future studies should examine the influence of training induced improvements in muscular strength and power on tackling ability.

3.6 Practical Applications

This study highlights the need for players to improve tackling ability as they progress higher in competitive standards. This is of particular importance to rugby league coaches developing young players. The standardised one-on-one tackling drill is a reliable and useful tool to evaluate and develop tackling technique.

The findings of this study demonstrate that well-developed muscular strength and upper-body power contribute to tackling ability in semi-professional rugby league players.

Although a significant correlation does not suggest causation, it does provide valuable insight into the physiological variables that effect tackling ability.

It can be assumed that as long as the technical aspects of tackling technique are adequately coached and practiced, then enhancements in muscular strength and power may serve as foundational components to underpin improvement in tackling ability. This is of particular importance to strength and conditioning specialists and rugby league coaches when evaluating and addressing deficiencies in player's tackling ability.

Chapter 4: The effect of strength and power training on tackling ability in semi-professional rugby league players

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4.1 Abstract

This study examined the influence of a strength and power program on tackling ability in rugby league players. Twenty-four semi-professional rugby league players (mean \pm SD age, 23.4 ± 3.1 yr) underwent tests of upper-body strength (3 repetition maximum [RM] bench press), lower-body strength (3RM squat), upper-body power (plyometric push-up) and lower-body power (countermovement jump). Muscular strength relative to body mass was also calculated. Tackling ability of the players was assessed using video analysis of a standardised one-on-one tackling drill. The players then underwent 8-weeks of strength and power training as part of their preseason training before being re-tested. Training resulted in significant ($p \leq 0.01$) improvements in absolute and relative measures of squat, bench press, countermovement jump peak power and plyometric push-up peak power. The strongest correlates of change in tackling ability were changes in 3RM squat ($r = 0.60$; $p < 0.01$) and squat relative to body mass ($r = 0.54$; $p < 0.01$). The players with the greatest improvements in 3RM squat and squat relative to body mass (i.e. responders) had significantly greater improvements in tackling ability than non-responding players ($p = 0.04$; $ES \geq 0.85$). A small, non-significant difference ($p = 0.20$; $ES = 0.56$) in tackling ability was found between responders and non-responders for lower-body power. The findings of this study demonstrate that the enhancement of lower-body muscular strength, and to a lesser extent muscular power, contribute to improvements in tackling ability in semi-professional rugby league players.

4.2 Introduction

Rugby league is a collision sport played internationally at junior and senior level. The game is intermittent in nature, characterized by bouts of high intensity running, collisions and tackling, separated by periods of lower intensity activity [3, 4]. The skillset required for rugby league is multifaceted with players requiring good ball handling ability (e.g. catching, passing and kicking), quick and accurate decision making, and the ability to perform effective tackles [57]. Rugby league players require well-developed aerobic fitness, speed, muscular strength and power, and agility to compete at an elite level [8]. An understanding of how these physical qualities relate to specific rugby league skills is essential for the development of specific coaching, and strength and conditioning programs.

Rugby league players are subjected to multiple physical collisions throughout a match, most of which occur while players are defending [2, 6]. In defense, players are required to make contact and tackle opposition players to halt their forward progress. The number of tackles that players are required to make is dependent on playing position [76]. Generally forwards will perform an average of 39 tackles, compared to the backs who perform an average of 16 tackles per match [76]. A large part of success in a collision sport such as rugby league is based on tackling ability, the capacity to dominate the tackle contest, and the ability to tolerate physical impacts [5]. Tackling technique, as examined by a one-on-one tackling drill has been found to be strongly associated with the proportion of missed tackles (negative) and the proportion of dominant tackles (positive) that players complete during match-play [10]. Therefore, the ability to perform a well-executed tackle is critical for the player to “win” the contact contest.

Several studies have examined the physiological and anthropometric correlates of tackling ability in sub-elite and professional rugby league players [13, 14, 16]. Well-developed acceleration (over a 10-metre sprint) and lower-body muscular power are associated with superior tackling ability in elite junior and professional rugby league players [13, 14, 16]. Furthermore, lower- and upper-body strength, as well as upper-body power have been shown to be significantly related to tackling ability in semi-professional rugby league players[85]. Although these findings provide important information on the relationship between selected physical qualities and tackling ability, significant correlations do not imply cause and effect. It has been proposed that if an appropriate amount of time was devoted to the skill of tackling, then improvements in muscular strength and power may transfer to improvements in tackling ability [13, 14, 16]. However, to date, no study has examined if improvements in muscular strength and power transfer to improvements in tackling ability. This study examined the influence of a strength and power program on tackling ability in an aim to provide insight into the possible mechanisms for eliciting improvements in tackling ability. It was hypothesized that players who experienced the greatest adaptations in muscular strength and power would demonstrate the greatest improvements in tackling ability.

4.3 Methods

Experimental Approach to the Problem

In order to test our hypothesis, a repeated-measures experimental design was used to evaluate changes that occurred in muscular strength and power qualities as well as tackling ability following an eight week training intervention. The players underwent tests of upper- and lower-body strength and power as well as an assessment of tackling ability prior to, and following an 8-week strength and power training program. Using a median-

split technique, players were then divided into “responders” or “non-responders” in each strength and power test based on the results of the strength and power testing. Pearson product moment correlations were also used to assess the relationship between training-induced changes in strength and power and tackling ability.

Subjects

Twenty-four senior (>18 years of age) rugby league players (mean \pm SD age, 23.4 \pm 3.1 yr) participated in this study. All players were from the same rugby league club. Players were classified as semi-professional as they received remuneration for playing rugby league but also relied on other forms of income. Players were free from injury and mid-way through a fifteen week preseason training program when they undertook the initial muscular strength and power testing, and the tackling assessment. All players received a detailed explanation of the study, including information on the risks and benefits. Written informed consent was obtained before the start of the study. The players were free to withdraw from the study at any time. All the procedures for this study were preapproved by the Australian Catholic University Ethics Reviewing Panel.

Muscular Strength

Upper- and lower-body muscular strength was assessed using a three repetition maximum (3RM) bench press and squat test, respectively. The players were familiar with the tests as they were part of routine testing. The tests were conducted 72 hours after the previous session and players were instructed to refrain from excessive exercise prior to the testing session. The testing occurred in the evening. Players were instructed to maintain their normal diet and hydration as they would for normal training sessions. For the 3RM test the players were instructed to perform progressively heavier loads using a standard 20kg

Olympic barbell, with 3 to 5 minutes rest between sets, until they attempted a load that they could lift for a maximum of three full range repetitions. A strength and conditioning specialist familiar with the players, supervised and guided the players to perform the squats to a below parallel thigh position (i.e. they descended to a position where the hip crease dropped below the knee). The intraclass correlation coefficients for test-retest reliability and typical error of measurement were 0.96 and 2.6% for the 3RM bench press and, 0.91 and 3.6% for the 3RM squat. Relative upper- and lower-body strength were calculated by dividing the 3RM of the bench press and squat by the player's body mass.

Muscular Power

Lower- and upper-body peak power were assessed with the players performing a countermovement jump (CMJ) and plyometric push-up on a force platform with a sampling rate of 500 Hz (Kistler 9290AD Force Platform, Kistler, Switzerland. To perform the CMJ, players were required to keep their hands on their hips for the duration of the movement. When instructed, the players dipped to a self-selected depth before explosively jumping as high as possible. Players had two attempts with their highest power output used for analysis. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for CMJ peak power were 0.81 and 3.5% respectively. For the plyometric push-up, the players were instructed to place their hands on the force platform while in the push-up position with their arms at full extension. When indicated, the players lowered their body before performing an explosive push-up that caused their hands to leave the platform. The players had two attempts with their highest power output recorded. All testing occurred at the start of a regular training session to limit fatigue related interference. The intraclass correlation coefficients for test-retest

reliability and typical error of measurement for the plyometric push-up were 0.97 and 3.8%, respectively.

Tackling Ability

The protocol used to examine tackling ability through the video analysis of a standardised 1-on-1 defensive drill was the same used in previous studies [13, 14, 16]. The drill was conducted in a 10 metre grid with video cameras (Canon Legria HV40, Japan) on the left, right and rear of the drill. The participants performed six consecutive tackles, three on the right shoulder and three on the left shoulder, on another participant of similar height and mass. The drill was performed at the start of a training session so that the participants were in a non-fatigued state. Tackling ability was assessed by a sport scientist using standardised technical criteria that has been used in previous studies of tackling ability in rugby league players [13, 14, 16].

The technical criteria included:

1. Contact made at the centre of gravity
2. Initial contact made with the shoulder
3. Body position square and aligned
4. Leg drive on contact
5. Watch the target onto the shoulder
6. Centre of gravity forward of the base of support

Each tackle received a score out of 6 (arbitrary units). Players were awarded 1 point for each criteria they achieved or 0 points if they failed to meet the criteria while performing a tackle. The players received an aggregate score (arbitrary units) from all 6 tackles,

which was then converted to a percentage. Movement velocity immediately prior to contact was calculated using video analysis (Silicon Coach, New Zealand). The intraclass correlation coefficient for test-retest reliability and typical error of measurement for tackling ability were 0.88 and 3.9%, respectively. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the movement velocity immediately prior to contact were 0.94 and 2.9%, respectively.

Training Program

All players underwent an 8-week strength and power training block as part of their preseason training. The players completed three strength and power training sessions per week. Due to the players being semi-professional and the lack of facilities within the club it was not possible to have the players perform their strength and power sessions separate to their field sessions. As a result, the players were required to perform skill based training as part of the same training session as the strength and power training. All the players performed the resistance program consisting of 3 sets of 3-6 repetitions. The strength and power program utilised heavy compound movements combined with explosive exercises (Table 4.1).

Table 4.1. Strength and power program employed during the 8-week training period.

Day 1				
Order	Exercise	Load (% 1RM)	Repetitions	Rest (s)
1a	Bench press	80-90%	3-6	90
1b	Explosive push ups	n/a	5	90
2a	Weighted chin ups	80-90%	3-6	90
2b	Explosive prone pull ups	n/a	5	90
3a	Shoulder press	80-90%	3-6	90
3b	DB Push press	40-50%	5	90
4	Weighted crunch matrix	n/a	20	30
Day 2				
1	Hang Clean	80-90%	3-6	90
2a	Back squat	80-90%	3-6	90
2b	Hurdle jumps	n/a	5	90
3a	Lunges	80-90%	3-6	90
3b	Step up with resistance bands	n/a	5	90
4	Front and lateral bridges	n/a	1 minute	30
Day 3				
1a	Bent row	80-90%	3-6	90
1b	Close grip push up	80-90%	3-6	90
2a	Smith machine bench throw	30%	5	90
2b	Medicine ball overhead throw	n/a	5	90
3a	Front squat	80-90%	3-6	90
3b	Prowler push	n/a	10 m	90
4	Torsinator	n/a	10	30

1RM = One repetition maximum. Where applicable loads are calculated as a percentage of the 1RM of squat and bench press

Statistical Analyses

Data were tested for normality using a Shapiro-Wilk test. We analysed (1) the effect of the training program on strength, power, and tackling ability; (2) the magnitude of improvements in tackling ability in players who did (i.e. “responders”) and did not (i.e. “non-responders”) show positive adaptations to the strength and power program, and (3) the relationship between training-induced changes in strength and power and changes in tackling ability. Firstly, pre- to post-training changes in strength, power, and tackling ability for the entire group were determined using a paired *t*-test. Secondly, players were divided into “responders” or “non-responders” in each strength and power test based on the median split of the results of the strength and power testing. A two-way group (responders vs. non-responders) x time (pre-training vs. post-training) repeated measures analysis of variance (ANOVA) was used to examine changes in strength, power and tackling ability. Cohen’s effect size (ES) statistic [79] was also used to determine the magnitude of any differences between pre- and post-training testing and between groups. Effect sizes of <0.2, 0.2-0.6, 0.61–1.2 1.21-2.0, and >2.0 were considered trivial, small, moderate, large, and very large, respectively [80]. Finally, Pearson product moment correlation coefficients were used to determine the relationships among changes in muscular strength and power and tackling ability. The level of significance was set at $p \leq 0.05$, and all data are reported as means \pm SD.

4.4 Results

Changes in strength, power and tackling ability

Table 4.2 shows the changes in muscular strength and power, and tackling ability following 8-weeks of training. A small difference in squat ($p \leq 0.01$; ES = 0.47) and a trivial difference in bench press ($p \leq 0.01$; ES = 0.14) was found between the pre- and post-

training intervention. Similarly, there was a significant improvement in strength relative to body mass. A moderate change was found in squat relative to body mass ($p \leq 0.01$; ES = 0.69) and a trivial difference in bench press relative to body mass ($p \leq 0.01$; ES = 0.14). A significant improvement in both CMJ ($p \leq 0.01$; ES = 0.27) and plyometric push up ($p \leq 0.01$; ES = 0.46) muscular power were also found. A small, significant improvement in tackling ability was also found ($p = 0.02$; ES = 0.26).

Table 4.2. Changes in strength, power and tackling ability following 8 weeks of training. †

	Pre-training	Post-training	Effect Size	Difference
Squat (kg)	126 ± 18	135 ± 18**	0.47	Small
Bench (kg)	113 ± 14	115 ± 15**	0.14	Trivial
Relative Squat (kg·kg ⁻¹)	1.37 ± 0.13	1.46 ± 0.15**	0.69	Moderate
Relative Bench (kg·kg ⁻¹)	1.23 ± 0.15	1.26 ± 0.14**	0.14	Trivial
CMJ Peak Power (W)	4639 ± 740	4843 ± 771**	0.27	Small
PPU Peak Power (W)	1486 ± 380	1663 ± 390**	0.46	Small
Tackling Ability (%)	70.0 ± 0.1	74.0 ± 0.1*	0.26	Small
Velocity into contact (m·s ⁻¹)	3.03 ± 0.38	3.06 ± 0.32	0.08	Trivial

Squat = 3RM squat; Bench = 3RM bench press; CMJ = counter movement jump; PPU = plyometric push up.

† Data are means ± SD. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

* Significant difference (p<0.05) between pre- and post-training.

** Significant difference (p<0.01) between pre- and post-training

Table 4.3. Relationship among changes in strength and power qualities and tackling ability in semi-professional rugby league players. †

	Squat	Bench	Rel Squat	Rel Bench	CMJ	PPU	Velocity	Tackle
Squat	1.00							
Bench	-0.01	1.00						
Rel Squat	0.99**	0.48	1.00					
Rel Bench	0.05	0.99**	0.11	1.00				
CMJ	0.20	-0.12	0.14	-0.10	1.00			
PPU	0.00	0.11	-0.04	0.10	0.09	1.00		
Velocity	-0.34	0.28	-0.35	0.26	0.09	-0.19	1.00	
Tackle	0.60**	-0.34	0.54**	-0.31	0.38	0.18	-0.18	1.00

Squat = change in 3RM squat; Bench = change in 3RM bench press; Rel Squat = change in squat relative to body mass; Rel Bench = change in bench press relative to body mass; CMJ = change in counter movement jump peak power; PPU = change in plyometric push up peak power; Velocity = change in average velocity prior to contact; Tackle = change in tackling ability.

† Data are reported as Pearson product-moment correlation coefficients, r.

** Significant at p<0.01.

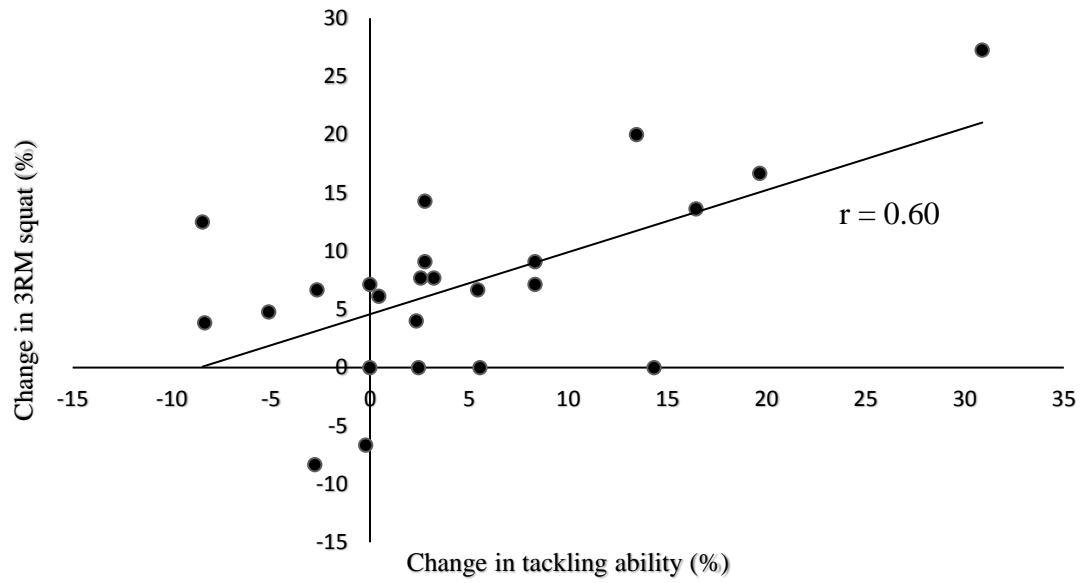


Figure 4.1. Relationship between change in 3RM squat and change in tackling ability.

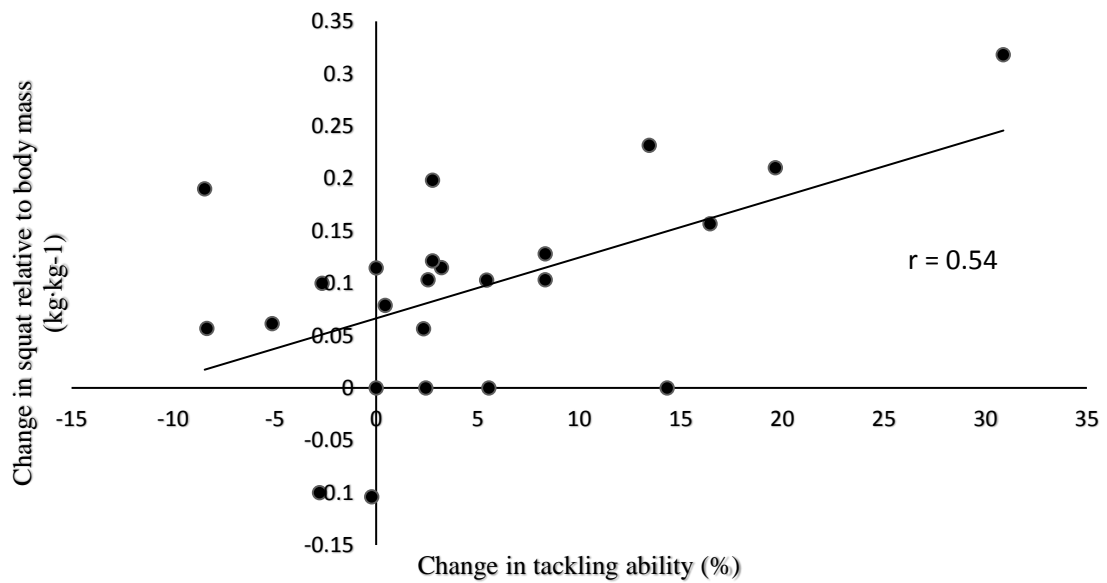


Figure 4.2. Relationship between change in squat relative to body mass and change in tackling ability.

Relationship between Strength and Power Qualities and Tackling Ability

Table 4.3 shows the relationships between changes in strength and power qualities and changes in tackling ability. The strongest correlates of change in tackling ability were change in 3RM squat ($r = 0.60$; $p < 0.01$) (Figure 4.1) and squat relative to body mass ($r = 0.54$; $p < 0.01$) (Figure 4.2).

Responders vs. Non-Responders

The changes in strength and power qualities in the “responders” and “non-responders” are shown in Table 4.4. The responders had significantly greater ($p < 0.01$) improvements in all strength and power tests. The magnitude of differences ranged from large to very large.

Table 4.5 shows the relationships between improvements in tackling ability and strength and power measures in the responders and non-responders. Players with the greatest improvements in the squat test (i.e. responders) had significantly greater improvements in tackling ability than the non-responders ($p = 0.04$; $ES = 0.90$). Similarly, players with the greatest improvements in relative squat strength also had significantly larger improvements in tackling ability ($p = 0.04$; $ES = 0.90$). A small difference in tackling ability (albeit non-significant), was found between the highest and lowest responders for CMJ peak power ($p = 0.17$; $ES = 0.56$). Only trivial to small relationships were found between bench press, relative bench press, plyometric push up and tackling ability.

Table 4.4. Changes in strength and power in responders and non-responders†

	Responders	Non-Responders	Effect Size	Difference
Squat (%)	12.7 ± 6.2**	1.4 ± 7.9	1.59	Large
Bench (%)	5.8 ± 2.3**	-1.1 ± 2.3	3.50	Very Large
Relative Squat (kg·kg ⁻¹)	0.17 ± 0.07**	0.02 ± 0.07	2.14	Very Large
Relative Bench (kg·kg ⁻¹)	0.07 ± 0.03**	-0.01 ± 0.03	2.67	Very Large
CMJ Peak Power (W)	503 ± 380**	-94.05 ± 155	2.06	Very Large
PPU Peak Power (W)	333 ± 169**	22 ± 132	2.05	Very Large

Squat = percentage change in 3RM squat; Bench = percentage change in 3RM bench press; CMJ = counter movement jump; PPU = plyometric push up.

† Data are means ± SD. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

** Significant difference (p<0.01) between groups.

Table 4.5. Percentage change in tackling ability of responders and non-responders. †

	Responders	Non-Responders	Effect Size	Difference
Squat	8.3 ± 10.5*	1.0 ± 5.9	0.90	Moderate
Bench	3.5 ± 7.8	5.8 ± 10.5	- 0.09	Trivial
Relative Squat	8.3 ± 10.5*	1.0 ± 5.9	0.90	Moderate
Relative Bench	3.5 ± 7.8	5.8 ± 10.5	- 0.09	Trivial
CMJ Peak Power	7.2 ± 10.6	2.1 ± 6.9	0.56	Small
PPU Peak Power	4.1 ± 7.1	5.2 ± 11.1	- 0.11	Trivial

Squat = percentage change in 3RM squat; Bench = percentage change in 3RM bench press; CMJ = counter movement jump; PPU = plyometric push up.

† Data are means ± SD. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

* Significant difference (p<0.05) between groups.

4.5 Discussion

This is the first study to examine if improvements in muscular strength and power transfer to improvements in tackling ability. It was hypothesized that players who experienced the greatest adaptations in muscular strength and power would demonstrate the greatest improvements in tackling ability. In support of our hypothesis, we found that players with the greatest improvements in both absolute and relative squat had significantly greater improvements in tackling ability than their non-responding peers. In addition, significant associations were found between improvements in lower-body strength and improvements in tackling ability. From a practical perspective, these findings demonstrate that improvements in lower-body strength are likely to lead to improvements in tackling ability in rugby league players.

This study found that the players who had the greatest improvements in lower-body strength and power also had the greatest improvements in tackling ability. These findings are in partial agreement with our hypothesis that players who experienced the greatest adaptations in muscular strength and power would demonstrate the greatest improvements in tackling ability. From the results of previous research, authors have speculated that improvements in lower-body strength and power could transfer into improvements in tackling ability [13, 14, 16]. The results of this study suggest that this is the case. Interestingly, the players that experienced the greatest improvements in upper-body strength and power did not experience any greater improvements in tackling ability than low responding players. This is somewhat surprising given that upper-body strength and power has been shown to be associated with tackling ability in semi-professional rugby league players [85].

There are numerous possible mechanisms for the superior improvements in tackling ability in the players with greater improvements in lower-body strength and power. The improvement in lower-body strength and power may have enhanced the players' ability to exert power into the tackle allowing them to improve leg drive through the tackle. Improvements in change of direction speed and acceleration may offer another possible explanation for the improvements in tackling ability. Gabbett [13] reported that better tacklers had greater acceleration and change of direction speed and suggested that change of direction speed may affect how well players position themselves prior to making contact. Studies have found that increased lower-body strength and power is associated with improved acceleration and change of direction speed [86-88]. Future research examining changes in tackling ability should also examine the changes in acceleration and change of direction speed.

The strongest correlates of change in tackling ability were improvements in 3RM squat ($r = 0.60$) and squat relative to body mass ($r = 0.54$). The coefficient of determination (r^2) for the 3RM squat and squat relative to body mass were 36% and 29%, respectively. Therefore, 64-71% of the variance in improved tackle ability is explained by factors in addition to, or other than improvements in lower-body strength. While this study provides an important step in explaining how changes in strength influence tackling ability, it must be acknowledged that additional factors (e.g. specific skill coaching and skill rehearsal) may explain a greater proportion of the change in tackling ability.

A small and significant improvement in tackling ability was found following 8-weeks of training. These findings are similar to an earlier study examining tackling ability in high-performance rugby league players which found a small but non-significant improvement

in tackling ability following 3-months of preseason training [10]. The combined results from these studies demonstrate that tackling ability can be improved in rugby league players in a relatively short amount of time provided that players receive an adequate training stimulus.

One limitation of this study is that training age or playing experience was not taken into consideration. Previous research has found that more experienced players have better tackling ability than less experienced players, suggesting that less experienced players have greater scope for improving tackling ability than experienced players [10, 16]. Furthermore, Baker and Newton [89] found that less experienced, weaker players experienced greater improvements in strength and power than stronger, more experienced players. Future studies examining the effect of strength and power training on tackling ability should examine the difference between experienced and less experienced players.

In conclusion, this is the first study to examine the influence of improvements in muscular strength and power on tackling ability in rugby league players. These findings demonstrate that increases in lower-body muscular strength, and to a lesser extent, muscular power, contribute to improvements in tackling ability in semi-professional rugby league players. Further research examining the relationship between muscular strength and power training on tackling ability in other competitive levels, such as professional and junior players, is warranted.

4.6 Practical Applications

Of particular note to rugby league coaches, this study demonstrates that significant improvements in tackling ability can be elicited in a relatively short amount of time.

Furthermore, this study has found that improvements in lower-body muscular strength and power are related to improvements in tackling ability in semi-professional rugby league players. This research highlights the importance of allowing adequate time for strength training during the preseason phase.

The findings of this study demonstrate that improvements in lower-body strength are likely to lead to improvements in tackling ability in rugby league players. It can be assumed that as long as the technical aspects of tackling ability are adequately coached and practiced, then enhancements in muscular strength and power may serve as foundational components to underpin improvement in tackling ability. This is of particular importance to strength and conditioning specialists and rugby league coaches when evaluating and addressing deficiencies in the tackling ability of players.

**Chapter 5: Changes in rugby league tackling ability during a competitive season:
the relationship with strength and power qualities**

Speranza, Michael J. A, Gabbett T. J, Greene, David A, Johnston, Rich D, Sheppard, Jeremy M. Changes in rugby league tackling ability during a competitive season: the relationship with strength and power qualities. *Journal Strength and Conditioning Research*. 2017; 31(12):3311- 3318.

5.1 Abstract

This study examined the relationship between changes in tackling ability, and muscular strength and power, during a semi-professional rugby league competitive season. Twelve semi-professional rugby league players (mean \pm SD age, 23.3 ± 2.0 yr) underwent tests of upper- and lower-body strength and power during the preseason period. Tackling ability was tested using video analysis of a standardised one-on-one tackling drill. Players repeated these tests after round 15 of a 25 match competitive season. Changes in 1RM squat ($r_s = 0.70$; $p < 0.02$) and squat relative to body mass ($r_s = 0.73$; $p < 0.01$) were significantly related to changes in tackling ability. Players with the greatest improvements in tackling ability (i.e. “responders”) maintained 1RM squat (effect size, $ES = 0.85$, $p = 0.09$) and squat relative to body mass ($ES = 0.82$, $p = 0.15$) more than the “non-responders”. The results of this study suggest that players who maintained lower-body strength were able to improve tackling ability during the competitive season, while reductions in lower-body strength were associated with decrements in tackling ability. This study highlights the importance of the development and maintenance of lower-body muscular strength for effective tackling performance throughout the rugby league season.

5.2 Introduction

Rugby league is an intermittent, contact sport played internationally at junior and senior levels. The sport is physically demanding requiring players to have well-developed endurance, speed, agility, strength, and power in order to compete at an elite level [8]. The sport is characterized by multiple physical contact efforts, known as the tackle contest. Gabbett et al. [90] reported that players were involved in 28 to 45 collisions per match with some players experiencing a physical contact once every 1.09 minutes during match-play. Thus, a large part of success in a contact sport such as rugby league is attributed to the ability to perform effective tackles, having a high tolerance for physical impacts, and the capacity to dominate the tackle contest [10].

In defense, players are required to make contact and tackle the opposition players in order to halt their forward progress. The number of tackles that players are required to make throughout a match is dependent on their playing position [76]. During professional match-play, wide running forwards make the greatest number of tackles with players in this position making an average of 25 tackles per match, with hit-up forwards, adjustables, and outside backs performing an average of 20, 15 and 8 tackles per match, respectively [6].

Most of the research examining tackling ability in rugby league has been performed using video analysis of a standardised one-on-one tackling drill. Tackling technique, as examined by the one-on-one tackle drill has been found to be strongly associated with the proportion of missed tackles (negative) and proportion of dominant tackles (positive) performed in rugby league match-play [10, 91]. Studies examining the physiological and anthropometric correlates of tackling ability in rugby league players have concluded that

high levels of acceleration (over a 10-metre sprint) and lower-body muscular power are associated with superior tackling ability in elite junior and professional rugby league players [13, 14, 16]. Lower- and upper-body strength, as well as upper-body power have been shown to be significantly related to tackling ability in semi-professional rugby league players [85]. Furthermore, it has been shown that the enhancement of lower-body muscular strength, and to a lesser extent muscular power, contribute to improvements in tackling ability in semi-professional rugby league players [92].

In a sport where it is essential that players physically dominate their opposition, well-developed muscular strength and power is beneficial [93]. During the preseason, training frequency and volume is relatively high to optimally develop muscular strength and power, as well as speed, agility, and aerobic capacity [94]. During the competitive rugby league season there is a reduction in frequency and volume of resistance training to allow a greater emphasis on recovery and skill-based training, with strength and conditioning programs aiming to maintain the muscular strength and power that were developed during the preseason phase of training [93]. Studies examining changes in muscular strength and power during the competition phase have reported varied results [93, 95, 96]. In a study examining professional rugby league players it was concluded that maximal strength and power could be maintained over the course of a 29-week season [93]. Argus et al. [95] examined changes in strength and power over a professional rugby union season and found that players were able to improve lower-body strength by 8.5% but experienced slight decrements in upper-body strength (-1.2%), and lower- (-3.3%) and upper-body (-3.4%) power, respectively. Mitchell et al. [96] found that in the collision sport of international rugby seven players experienced decreases in lower-body strength (4 to 9%) but were able to maintain or improve upper-body strength during the course of a 28-week

competitive season. Interestingly, it was also found that forwards experienced moderate decrements in lower-body muscular power during the season, whereas the backs experienced moderate improvements [96].

Although tackling is a fundamental skill in rugby league there is very limited research into the effect that training, and match-play has on tackling performance. Only one study has examined the influence of specific coaching on tackling technique [10]. Gabbett and Ryan [10] found that there was a small (non-significant) improvement in tackling technique following a 3-month skills training program in professional rugby league players. The authors found that the greatest improvements in tackling technique occurred in the players with the lowest initial tackling technique [10]. Following the 3-month training program, players more frequently made initial contact with their shoulder, made contact with the target's centre of gravity, and kept their centre of gravity in front of their base of support [10]. The aforementioned study was conducted during the preseason phase of training, therefore the influence of match-play exposure on tackling ability was not examined. To date no study has examined the impact of match-play on tackling ability.

Previous research has found that an improvement in lower-body muscular strength, contributes to improvements in tackling ability in semi-professional rugby league players during a preseason phase of training [92]. To date no study has examined the influence of changes in muscular strength and power has on tackling ability during the competition phase. The purpose of this study was to investigate changes in tackling ability during a competitive season, and determine if these changes were associated with changes in muscular strength and power. It was hypothesized that players who were able to maintain

or improve muscular strength and power would experience the greatest improvements in tackling ability.

5.3 Methods

Experimental Approach to the Problem

A repeated measures experimental design was used to evaluate changes that occurred in muscular strength and power qualities as well as tackling ability from the end of preseason training phase to mid-way through the competition season. The players underwent tests for upper- and lower-body strength and power, as well as an assessment of tackling ability before the commencement of round 1 of the season, and after week-16 (round 13) of the competitive season. Using a median split technique, players were divided into either “responders” or “non-responders” based on the changes in the assessment of tackling ability.

Subjects

Twelve senior semi-professional rugby league players (mean \pm SD age, 23.3 ± 2.0 yr; mass, 96.5 ± 10.3) participated in this study. All players were over the age of 18 years. All players were from the same rugby league club, and were competing in the Queensland Cup competition. The Queensland Cup is a ‘feeder’ competition to the elite National Rugby League competition. Players were classified as semi-professional as they received remuneration for playing rugby league but also relied on other forms of income. Players were free from injury and in week eight of a fifteen week preseason training program when they undertook the initial muscular strength and power testing, and the tackling assessment. Throughout the entire preseason the players completed three training sessions a week which consisted of strength and conditioning elements as well as skill based

training. All players received a detailed explanation of the study, including information on the risks and benefits. Written informed consent was obtained before the start of the study. The players were free to withdraw from the study at any time. All the procedures for this study were preapproved by the Australian Catholic University Ethics Reviewing Panel.

Strength Testing

Upper- and lower-body muscular strength was assessed using a one repetition maximum (1RM) bench press and squat test, respectively. The players were familiar with the tests as they were part of routine testing. The tests were conducted 72 hours after the previous training session and players were instructed to refrain from excessive exercise 24 hours prior to the testing session. The testing occurred in the evening. Players were instructed to maintain their normal diet and hydration as they would for normal training sessions. For the 1RM test the players were instructed to perform progressively heavier loads using a standard 20 kg Olympic barbell, with 3 to 5 minutes rest between sets, until they attempted a load that they could lift for a maximum of one full range repetition. A strength and conditioning specialist familiar with the players, supervised and guided the players through the strength tests. Players were required to perform the squats to a below parallel thigh position (i.e. they descended to a position where the hip crease dropped below the knee). Bench press was performed in a controlled manner for the bar to touch the chest and press the bar upwards until arms were fully extended. The intraclass correlation coefficients for test-retest reliability and typical error of measurement were 0.98 and 2.8% for the 1RM bench press and, 0.96 and 3.0% for the 1RM squat. Relative upper- and lower-body strength were calculated by ratio scaling, dividing the 1RM of the bench press and squat by the player's body mass. Rugby league research has shown that ratio scaling

is as effective as other more complex methods, such as allometric scaling for the calculation of relative strength [97].

Power Testing

Lower- and upper-body peak power were assessed with the players performing a countermovement jump (CMJ) and plyometric push-up on a force platform with a sampling rate of 500 Hz (Kistler 9290AD Force Platform, Kistler, Switzerland). To perform the CMJ, players were required to keep their hands on their hips for the duration of the movement. When instructed, the players dipped to a self-selected depth before explosively jumping as high as possible. Players had two attempts with their highest power output used for analysis. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for CMJ peak power were 0.81 and 3.5% respectively. For the plyometric push-up (PPU), players were instructed to place their hands on the force platform while in the push-up position with their arms at full extension. When indicated, players lowered their body before performing an explosive push-up that caused their hands to leave the platform. The players had two attempts with their highest power output recorded. All testing occurred at the start of a regular training session to limit fatigue-related interference. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the plyometric push-up were 0.97 and 3.8%, respectively.

Tackling Technique

The protocol used to examine tackling ability through the video analysis of a standardised 1-on-1 defensive drill has been previously described [13, 14, 16]. The drill was conducted in a 10 metre grid with video cameras (Sony AX100, Sony, Japan) on the left, right and

rear of the drill. The participants performed six consecutive tackles, three on the right shoulder and three on the left shoulder, on another participant of similar height and mass. The drill was performed at the start of a training session so that the participants were in a non-fatigued state. Tackling ability was assessed by a sport scientist using standardised technical criteria described previously [13, 14, 16].

The technical criteria included:

1. Contact made at the centre of gravity
2. Initial contact made with the shoulder
3. Body position square and aligned
4. Leg drive on contact
5. Watch the target onto the shoulder
6. Centre of gravity forward of the base of support

Each tackle received a score out of 6 (arbitrary units). Players were awarded 1 point for each criteria they achieved or 0 points if they failed to meet the criteria while performing a tackle. The players received an aggregate score (arbitrary units) from all 6 tackles, which was then converted to a percentage. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for tackling ability were 0.88 and 3.9%, respectively.

Muscular strength and power, and tackling ability were retested in the week following the round fifteen match. During this period the team were involved in thirteen matches over a sixteen week period. The players competed in an average of 8 games (range: 3 to 13) in the period between round 1 and round 15.

Statistical Analysis

Due to the non-normal distribution of the data, non-parametric tests and magnitude based inferences were used. Pre- to post-training changes in strength, power, and tackling ability for the entire group were first analysed using a Wilcoxon signed rank test. Spearman's correlation coefficients (r_s) and 95% confidence intervals (CI) were used to determine the relationships among changes in muscular strength and power and tackling ability. The level of significance was set at $P \leq 0.05$. Based on changes in tackling ability over the season, players were then divided into "responders" ($n=6$) or "non-responders" ($n=6$) using a median split. Mann Whitney-U test was used to test for differences in muscular strength and power, and tackling ability between the "responders" and "non-responders". A Wilcoxon signed rank test was used to examine the within group differences in muscular strength and power, and tackling ability in the "responders" and "non-responders". Cohen's effect size (ES) statistic was also used to determine the magnitude of any differences in pre-season and in-season testing between groups [79]. Effect sizes of <0.2 , $0.2-0.6$, $0.61-1.2$, $1.21-2.0$, and >2.0 were considered trivial, small, moderate, large, and very large, respectively [80].

5.4 Results

Changes in Strength, power and tackling ability

Table 5.1 shows the changes in muscular strength and power, and tackling ability following 15 rounds of competition. There was a significant decrease in upper-body power ($ES = -0.68$, $p < 0.01$). There was no significant ($p > 0.05$) change in upper or lower-body muscular strength, or lower-body power. There was a small, insignificant increase in tackling ability ($ES = 0.24$, $p = 0.38$).

Table 5.1. Changes in body mass, muscular strength and power, and tackling ability †

	Pre-season	Mid-season	Δ	Effect Size
Body Mass (kg)	97.0 \pm 10.6	96.5 \pm 10.3	-0.5 \pm 1.6	-0.04
Squat (kg)	157.9 \pm 19.4	155.4 \pm 18.5	-2.5 \pm 11.3	-0.13
Bench Press (kg)	121.9 \pm 21.4	123.8 \pm 17.9	1.9 \pm 6.3	-0.10
Relative Squat (kg·kg ⁻¹)	1.63 \pm 0.16	1.62 \pm 0.19	-0.01 \pm 0.10	-0.08
Relative Bench Press (kg·kg ⁻¹)	1.26 \pm 0.20	1.29 \pm 0.16	0.03 \pm 0.07	0.14
CMJ Peak Power (W·kg ⁻¹)	60.6 \pm 7.2	56.6 \pm 5.5	-4.1 \pm 6.9	-0.64
PPU Peak Power (W·kg ⁻¹)	20.8 \pm 3.4	18.4 \pm 3.9 [#]	-2.4 \pm 1.5	-0.68
Tackling Ability (%)	68.2 \pm 0.1	70.1 \pm 0.1	1.9 \pm 7.5	0.24

Squat = 1RM squat; Bench = 1RM bench press; CMJ = counter movement jump; PPU = plyometric push up.

Δ = change in body mass, strength, power and tackle ability from pre-season to mid-season.

† Data are means \pm SD.

Effect size of changes from pre-season to mid-season, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

[#] Significant difference (p<0.01) between pre-season and mid-season.

Relationship between Strength and Power Qualities and Tackling Ability

Table 5.2 shows the relationships between the changes in strength and power qualities and changes in tackling ability. Change in 1RM squat ($r_s = 0.70$ [0.14-0.89]; $p < 0.05$) and change in squat relative to body mass ($r_s = 0.73$ [0.25-0.92]; $p < 0.01$) were significantly related to change in tackling ability.

Responders vs. Non-responders

The responders and non-responders were exposed to a similar number of games, 8.0 ± 3.8 and 8.3 ± 3.9 respectively. The changes in strength and power in the responders and non-responders are displayed in Table 5.3. Players with the greatest improvements in tackling ability (i.e. “responders”) maintained 1RM squat (ES = 0.86, $p = 0.09$) and squat relative to body mass (ES = 0.82, $p = 0.15$) more than the “non-responders”. “Responders” showed a larger decrement in CMJ than the “non-responders” (ES = -0.84, $p = 0.26$)

Table 5.2. Relationship among changes in physical qualities and tackling ability in semi-professional rugby league players †

	Body Mass	Squat	Bench	Rel Squat	Rel Bench	CMJ	PPU	Tackle
Body Mass	1.00							
Squat	-0.38 (-0.86 to 0.35)	1.00						
Bench	-0.24 (-0.79 to 0.38)	-0.37 (-0.81 to 0.24)	1.00					
Rel Squat	-0.62 (-0.66 to 0.62)	0.91 [#] (0.80 to 0.99)	-0.37 (-0.84 to 0.26)	1.00				
Rel Bench	0.10 (-0.56 to 0.61)	-0.48 (-0.87 to 0.07)	0.89 [#] (0.54 to 1.00)	-0.34 (-0.83 to 0.27)	1.00			
CMJ	0.37 (-0.32 to 0.85)	-0.32 (-0.81 to 0.33)	-0.30 (-0.77 to 0.29)	-0.28 (-0.83 to 0.35)	-0.26 (-0.72 to 0.37)	1.00		
PPU	0.24 (-0.57 to -0.80)	0.04 (-0.60 to 0.79)	-0.10 (-0.72 to 0.49)	0.10 (-0.61 to 0.77)	-0.16 (-0.75 to 0.47)	0.40 (-0.16 to 0.77)	1.00	
Tackle	-0.30 (-0.82 to 0.38)	0.70* (0.21 to 0.92)	-0.01 (-0.63 to 0.68)	0.73 [#] (0.17 to 0.98)	0.07 (-0.56 to 0.65)	-0.38 (-0.80 to 0.24)	-0.15 (-0.71 to 0.55)	1.00

Squat = change in 1RM squat; Bench = change in 1RM bench press; Rel Squat = change in 1RM squat relative to body mass; Rel Bench = change in 1RM bench press relative to body mass; CMJ = change in counter movement jump peak power; PPU = change in plyometric push up peak power; Tackle = change in tackling ability.

† Data are reported as Spearman's rank order correlation coefficients, r_s and 95% confidence interval (in parentheses).

* Significant at $p < 0.05$.

[#] Significant at $p < 0.01$.

Table 5.3. Changes in body mass, strength, power and tackling ability in responders and non-responders[†]

	Responders		Non-Responders		Δ Responders	Δ Non-responders	Effect Size
	Pre-season	Mid-season	Pre-season	Mid-season			
Body Mass (kg)	96.5 \pm 9.8	96.6 \pm 10.6	97.5 \pm 12.2	96.4 \pm 11.1	0.1 \pm 1.4	-1.1 \pm 1.8	0.74
Squat (kg)	148.3 \pm 20.6	150.4 \pm 11.0	167.5 \pm 13.7	160.4 \pm 23.9	2.1 \pm 11.2	-7.1 \pm 10.2	0.86
Bench (kg)	117.5 \pm 8.9	120.0 \pm 10.5	126.3 \pm 29.6	127.5 \pm 23.6	2.5 \pm 5.9	1.3 \pm 7.2	0.19
Relative Squat (kg·kg ⁻¹)	1.55 \pm 0.16*	1.57 \pm 0.20	1.72 \pm 0.11	1.67 \pm 0.18	0.03 \pm 0.12	-0.06 \pm 0.08	0.82
Relative Bench (kg·kg ⁻¹)	1.22 \pm 0.10	1.25 \pm 0.10	1.30 \pm 0.28	1.33 \pm 0.21	0.02 \pm 0.05	0.03 \pm 0.08	-0.03
CMJ Peak Power (W·kg ⁻¹)	61.3 \pm 7.5	54.4 \pm 3.0	60.0 \pm 7.5	58.7 \pm 6.9	-6.9 \pm 8.7	-1.3 \pm 3.4	-0.84
PPU Peak Power (W·kg ⁻¹)	21.6 \pm 2.8	18.9 \pm 2.3 [‡]	20.1 \pm 4.1	17.8 \pm 5.0 [‡]	-2.6 \pm 1.4	-2.3 \pm 1.7	-0.25
Tackling Ability (%)	64.4 \pm 10.6	71.8 \pm 8.5 [‡]	72.2 \pm 3.9	68.5 \pm 4.2 [‡]	7.4 \pm 7.0 [#]	-3.7 \pm 1.4	2.21

Δ Responders = change in body mass, strength, power and tackling ability from pre-season to mid-season in “responders”.

Δ Non-responders = change body mass, in strength, power and tackling ability from pre-season to mid-season in “non-responders”.

[†] Data are means \pm SD.

Effect size of changes between groups, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

* Significant difference (p<0.05) between groups.

Significant difference (p<0.01) between groups.

[‡] Significant difference (p<0.05) within groups.

Table 5.4. Changes in tackling ability of “responders” and “non-responders”†

	Responders		Non-responders		Δ Responders	Δ Non- responders	Effect Size
	Pre-season	Mid-season	Pre-season	Mid-season			
Contact centre of gravity (AU)	4.8 \pm 2.4	5.7 \pm 0.8	5.8 \pm 0.4	5.8 \pm 0.4	0.8 \pm 1.6	0.2 \pm 0.4	0.57
Initial contact shoulder (AU)	5.3 \pm 1.2	5.8 \pm 0.4	5.7 \pm 0.8	5.7 \pm 0.8	0.5 \pm 1.4	-	0.51
Square and aligned (AU)	1.5 \pm 1.4	2.3 \pm 2.0	2.2 \pm 1.7	2.5 \pm 1.1	0.8 \pm 2.0	-0.2 \pm 1.2	0.61
Leg drive on contact (AU)	4.2 \pm 1.0	4.8 \pm 1.2	4.8 \pm 1.8	3.7 \pm 1.6	0.7 \pm 1.4	-1.0 \pm 2.0	0.97
Watch target onto shoulder (AU)	1.8 \pm 2.1	2.3 \pm 1.4	1.5 \pm 1.8	1.3 \pm 2.0	0.5 \pm 2.9	0.0 \pm 1.8	0.21
Centre of gravity over base (AU)	5.5 \pm 0.8	4.8 \pm 1.9	6.0 \pm 0.0	5.7 \pm 0.5	-0.7 \pm 1.2	-0.3 \pm 0.5	-0.36
Tackling Ability (AU)	23.2 \pm 1.5	25.8 \pm 3.1 [†]	26.0 \pm 1.4	24.7 \pm 1.5 [†]	2.7 \pm 2.5 [#]	-1.3 \pm 0.5	2.21
Tackling Ability (%)	64.4 \pm 10.6	71.8 \pm 3.9 [†]	72.2 \pm 3.9	68.5 \pm 4.2 [†]	7.4 \pm 7.0 [#]	-3.7 \pm 1.4	2.21

Δ Responders = change in tackling ability technical criteria from pre-season to mid-season in “responders”.

Δ Non-responders = change in tackling ability technical criteria from pre-season to mid-season in “non-responders”.

† Data are means \pm SD.

Each variable represents a score from a possible score of 6 (i.e. the sum of 6 trials). Tackling ability score represents the total score from a possible score of 36 (i.e. the sum of the technical criteria), and is also expressed as a percentage.

Effect size of changes between groups, <0.2 = trivial; 0.2-0.6 = small; 0.61-1.2 = moderate; 1.21-2.0 = large; >2.0 = very large.

[#] Significant difference (p<0.01) between groups.

[†] Significant difference (p<0.05) within groups.

Table 5.4 illustrates the changes in tackling ability between “responders” and “non-responders”. From preseason to mid-season testing, the “responders” had greater improvements in the regularity that they maintained a square and aligned position ($p=0.87$; $ES = 0.61$) and produced leg drive on contact ($p=0.14$; $ES = 0.97$) than the “non-responders”. The “non-responders” experienced decrements in the two aforementioned technical criteria.

5.5 Discussion

This is the first study to examine changes in tackling ability and its relationship with changes in muscular strength and power during a competitive season. The results of this study are in partial agreement with our hypothesis that players who were able to maintain or improve muscular strength and power would experience the greatest improvements in tackling ability. In the present study, players who maintained lower-body maximal strength during the competitive season also elicited improvements in tackling ability, while the players who experienced reductions in lower-body strength experienced decrements in tackling ability. Changes in upper-body strength or muscular power were not related to changes in tackling ability.

Previous research has shown that enhancements in lower-body muscular strength contribute to improvements in tackling ability in semi-professional rugby league players [92]. The results of this study demonstrate that tackling ability can be improved in the absence of improvements in lower-body strength. It would appear that the stimulus of match-play, training and coaching is sufficient to elicit improvements in tackling ability if lower-body strength can be maintained. Conversely, the players who experienced a

decrement in lower-body strength also experienced a significant reduction in tackling ability.

This study highlights the importance of maintaining and developing lower-body muscular strength for effective tackling performance throughout the rugby league season. It would be misleading however, to suggest that lower body strength is the most important physical quality for rugby league players as tackling is only one element of the game. However, it has been shown that players with superior lower-body strength are involved in more repeated high-intensity effort bouts and collisions, and also demonstrate accelerated post-match recovery [12, 98]. Coupled with the results of the present study, these findings support the importance of developing lower-body strength in rugby league players.

It was found in this study that the players who experienced the greatest improvements in tackling ability (i.e. “responders”) were able to maintain lower-body maximal strength whereas the “non-responders” had a 4.0% and 3.4% decrement in 1RM squat and squat relative to body mass, respectively. During the mid-season testing, the “responders” moderately improved the regularity of leg drive upon contact compared to preseason testing. In comparison, the “non-responders” showed a reduction in this technical criterion. It is possible that a decrement in lower-body strength may have a negative influence on a players’ ability to exert power in the tackle through leg drive, thereby adversely affecting tackling ability.

The strongest correlates of changes in tackling ability were changes in 1RM squat and squat relative to body mass. The coefficient of determination (r^2) for the 1RM squat and squat relative to body mass were 49% and 53%, respectively. Therefore, 49-53% of the

variance in the change in tackling ability is explained by changes in lower-body strength. However, while this study provides an important step in explaining how changes in lower-body strength influence changes in tackling ability, it must be acknowledged that additional factors, such as changes in technical or perceptual skill may further explain a proportion of the change in tackling ability.

Players who improved their tackling ability had inferior lower-body strength and also experienced a larger decrement in lower body power than the “non-responders” from preseason to midseason. These results are surprising given that previous rugby league research has found a positive association between vertical jump and tackling ability [14, 16, 85]. Research conducted by Johnston et al. [98] found that post-match fatigue was reduced in players with well-developed lower body strength. Although we performed all testing 72 hours post intense exercise, it is possible that the inferior lower-body strength contributed to an increased carryover of fatigue from matches, potentially explaining the decreases in muscular power found in the “responders” groups. The results of this study suggest that improvements in muscular power do not play a significant role in eliciting improvements in tackling ability in semi-professional rugby league players.

Previous research has found that tackling ability, as examined using the standardised one-on-one tackle drill is strongly associated with match-play tackling performance, in particular the proportion of missed tackles and dominant tackles that players perform [10, 91]. Given that this study has found that tackling ability does change (both positively and negatively) in individual players throughout the competitive season, one would assume that it would also affect the player’s match-play tackling performance. It is recommended

that future studies examine the influence of changes in tackling ability on match-play tackling performance throughout a competitive season.

5.6 Practical Applications

This study highlights the importance of maintaining and developing lower-body muscular strength for effective tackling performance throughout the rugby league season. It has been demonstrated in this study that exposure to match-play, training and coaching is sufficient to elicit improvements in tackling ability during the competitive season if lower-body strength can be maintained. Therefore it is imperative for strength and conditioning specialists to implement an appropriate and adequate strength training stimulus to maintain muscular strength in rugby league players throughout the competitive season.

Of particular note to rugby league coaches, this study has shown that players can experience changes in tackling ability (both positive and negative) over the course of the competitive season. Given that previous research has found that tackling ability as examined by a one-on-one tackling drill has been found to be strongly associated with the proportion of missed tackles (negative) and the proportion of dominant tackles (positive) that players are involved in during match-play, one could assume that any changes to tackling ability will affect match-play tackling performance [10, 91]. Therefore the standardised one-on-one tackle drill may be a useful monitoring test to evaluate players tackling ability throughout the competitive season.

**Chapter 6: Relationship between a standardised tackling proficiency test and
match-play tackle performance in semi-professional rugby league players**

Speranza, Michael J. A, Gabbett T. J, Johnston, Rich D, Sheppard, Jeremy M. Relationship between standardised tackling proficiency test and match-play tackle performance in semi-professional rugby league. *International Journal of Sports Physiology and Performance*. 2015; 10(6):754-760.

6.1 Abstract

This study examined the relationships between tackling ability, playing position, muscular strength and power qualities, and match-play tackling performance in semi-professional rugby league players. Sixteen semi-professional rugby league players (mean \pm SD age, 23.8 ± 1.9 yr) underwent tests for muscular strength and power. Tackling ability of the players was tested using video analysis of a standardised one-on-one tackling drill. After controlling for playing position, players were divided into “good tacklers” or “poor tacklers” groups based on the median split of the results of the one-on-one tackling drill. A total of 4547 tackles were analysed from video recordings of 23 matches played throughout the season. Maximal squat was significantly associated with tackling ability ($r = 0.50$; $p < 0.05$) and with the proportion of dominant tackles ($r_s = 0.64$; $p < 0.01$). Forwards performed more tackles ($p = 0.013$; $ES = 1.49$), with a lower proportion of missed tackles ($p = 0.03$; $ES = 1.38$) than backs. “Good tacklers” were involved in a larger proportion of dominant tackles and smaller proportion of missed tackles than “poor tacklers”. These findings demonstrate that lower body strength contributes to a more effective tackling ability during both a standardised tackling assessment and match-play. Furthermore, players with good tackling ability perform a higher proportion of dominant tackles, and miss a smaller proportion of tackles. These results provide further evidence of the practical utility of an off-field tackling assessment in supplying information predictive of tackling performance in competition.

6.2 Introduction

Rugby league is a collision sport played internationally at junior and senior level. The game is intermittent in nature, characterized by bouts of high intensity running, collisions and tackling, separated by periods of lower intensity activity [3, 4]. The skillset required for rugby league is multifaceted with players requiring good ball handling ability (e.g. catching, passing and kicking), quick and accurate decision-making, and the ability to perform effective tackles [57]. Rugby league players require well-developed aerobic fitness, speed, muscular strength and power, and agility to compete at an elite level [8]. An understanding of how these physical qualities relate to specific rugby league skills is essential for the development of specific coaching, and strength and conditioning programs.

Rugby league players perform multiple physical collisions throughout a match, most of which occur while players are defending [2, 6]. In defence, players are required to make contact and tackle opposition players to halt their forward progress. The number of tackles that players are required to make is dependent on playing position [9]. Generally forwards will perform an average of 26.1 tackles, compared to the backs who perform an average of 10.7 tackles per match [9]. A large part of success in a collision sport such as rugby league is based on tackling ability, the capacity to dominate the tackle contest, and the ability to tolerate physical impacts [5]. Tackling technique, as examined by a standardised one-on-one tackling drill has been found to be strongly associated with the proportion of missed tackles (negative) and the proportion of dominant tackles (positive) in professional rugby league match-play [10]. To date no research has examined how the standardised one-on-one tackling drill is related to match-play tackling performance at a semi-professional level. In addition, no study has examined other match-play tackling

performance indicators such as off-loads conceded, positive defensive tackles (e.g. forcing the opposition backwards from the point of initial contact), or errors forced as the result of a tackle.

Several studies have examined the physiological and anthropometric correlates of tackling ability in sub-elite and professional rugby league players [13, 14, 16]. Well-developed acceleration (over a 10-metre sprint) and lower-body muscular power are associated with superior tackling ability in elite junior and professional rugby league players [13, 14, 16]. Furthermore, lower- and upper-body strength, as well as upper-body power have been shown to be significantly related to tackling ability in semi-professional rugby league players (unpublished observations). To date no study has examined the relationship between physiological qualities and match-play tackling performance.

The purpose of this study was to i) investigate the relationship between tackling ability (as assessed using a standardised one-on-one tackle drill) and match-play tackling performance; ii) determine the relationship between muscular strength and match-play tackling performance; iii) examine the relationship between playing position, tackling ability and match-play tackling performance; and iv) compare tackle characteristics between players with good and poor tackling ability.

6.3 Methods

Sixteen senior semi-professional rugby league players (mean \pm SD age, 23.8 ± 1.9 yr; mean \pm SD mass, 94.2 ± 8.4 kg) participated in this study. All players were from the same rugby league club competing in the Queensland Intrust Super Cup, a state-wide competition, one tier below the elite National Rugby League in Australia. Players were

classified as semi-professional as they received remuneration for playing rugby league but also relied on other forms of income. Players were free from injury and mid-way through a fifteen week preseason training program when they undertook the muscular strength and power testing, and the tackling assessment. All players received a detailed explanation of the study, including information on the risks and benefits. Written informed consent was obtained before the start of the study. The players were free to withdraw from the study at any time. All the procedures for this study were approved by the Australian Catholic University Ethics Review Panel prior to data collection.

Players were categorised into two playing positions; forwards (prop, second row, lock, and hooker) and backs (halfback, five-eighth, centre, wing and fullback). The breakdown of the players were forwards (n=8; mean \pm SD age, 24.5 ± 1.7 yr; mean \pm SD mass, 95.4 ± 10.4 kg), and backs (n=8; mean \pm SD age, 23.1 ± 2.1 yr; mean \pm SD mass, 93.0 ± 6.3 kg).

Upper- and lower-body muscular strength was assessed using a one repetition maximum (1RM) bench press and squat test, respectively. The players were familiar with the tests as they were part of routine testing. The tests were conducted 72 hours after the previous session and players were instructed to refrain from excessive exercise prior to the testing session. The testing occurred in the evening. Players were instructed to maintain their normal diet and hydration as they would for normal training sessions. For the 1RM test the players were instructed to perform progressively heavier loads using a standard 20 kg Olympic barbell, with 3 to 5 minutes rest between sets, until they attempted a load that they could lift only once. A strength and conditioning specialist familiar with the players, supervised and guided the players to perform the squats to a below parallel thigh position

(i.e. they descended to a position where the hip crease dropped below the knee). The intraclass correlation coefficients for test-retest reliability and typical error of measurement were 0.98 and 2.8% for the 1RM bench press and, 0.96 and 3.0% for the 1RM squat. Relative upper- and lower-body strength were calculated by dividing the 1RM of the bench press and squat by the player's body mass.

Lower- and upper-body peak power were assessed with the players performing a countermovement jump (CMJ) and plyometric push-up (PPU) on a force platform with a sampling rate of 500 Hz (Kistler 9290AD Force Platform, Kistler, Switzerland). To perform the CMJ, players were required to keep their hands on their hips for the duration of the movement. When instructed, the players dipped to a self-selected depth before explosively jumping as high as possible. Players had two attempts with their highest power output used for analysis. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for CMJ peak power were 0.81 and 3.5% respectively. For the PPU, the players were instructed to place their hands on the force platform while in the push-up position with their arms at full extension. When indicated, the players lowered their body before performing an explosive push-up that caused their hands to leave the platform. The players had two attempts with their highest power output recorded. All testing occurred at the start of a regular training session to limit fatigue related interference. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for the plyometric push-up were 0.97 and 3.8%, respectively.

The protocol used to examine tackling ability through the video analysis of a standardised 1-on-1 defensive drill was the same used in previous studies.[13, 14, 16] The drill was

conducted in a 10 metre grid with video cameras (Canon Legria HV40, Japan) on the left, right and rear of the drill. A diagram of the drill is shown in Figure 6.1. The participants performed six consecutive tackles, three on the right shoulder and three on the left shoulder, on another participant of similar height and mass. The drill was performed at the start of a training session so that the participants were in a non-fatigued state. Tackling ability was assessed by a sport scientist using standardised technical criteria that have been used in previous studies of tackling ability in rugby league players.[13, 14, 16]



Figure 6.1. Standardised 1-on-1 tackling drill

The technical criteria included:

1. Contact made at the centre of gravity
2. Initial contact made with the shoulder
3. Body position square and aligned
4. Leg drive on contact
5. Watch the target onto the shoulder
6. Centre of gravity forward of the base of support

Each tackle received a score out of 6 (arbitrary units). Players were awarded 1 point for each criteria they achieved or 0 points if they failed to meet the criteria while performing

a tackle. The players received an aggregate score (arbitrary units) from all 6 tackles, which was then converted to a percentage. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for tackling ability were 0.88 and 3.9%, respectively.

Twenty-three semi-professional rugby league matches played in the 2014 season were analysed from video recordings of the matches. A total of 4547 tackle involvements were examined. The players competed in an average of 15 games (range: 5 to 22) and were involved in an average of 18 tackle events per match (range: 4 to 33). The data on each of the player's involvement in a tackle contest was recorded. Data on the descriptors of the tackle events included site of initial contact and order of involvement. The data recorded on tackle outcomes were positive tackles, if the tackle was dominant or not, if the tackle was successful or not, if that tackle conceded an offload and if the tackle caused an error. Definitions for tackles and related characteristics are shown in Table 6.1.

Table 6.1. Definitions for tackles descriptors and outcomes

Descriptors	
Tackle	A successful tackle occurs when the ball carrier is held by one or more of the opposing players and either the ball or hand holding the ball makes contact with the ground or the ball carrier cannot make any further progress [21].
Order of contact	Players were coded for when they became involved in the tackle, either first, second or third or more.
Contact zone	Where the player made initial contact with the ball carrier was recorded. The contact areas were classified into 4 zones: Zone- 1 - Lower legs: below the player's knees; Zone- 2 - Hip and thigh: from the player's hip to the knee; Zone- 3 – Torso: from the bottom of the player's ribs to the player's hips; Zone- 4 – Chest: from the level of the ribs to the shoulders.
Outcomes	
Dominant tackle	A tackle was deemed to be dominant if the time from when the ball carrier's forward momentum has been halted to when the ball touches the foot during the play the ball exceeded four seconds or the tackle resulted in an offensive error.
Missed tackle	Any unsuccessful attempt to complete a tackle where the tackler/defender has made contact with the ball carrier and they have broken from the tackle before it was completed [21].
Positive tackle	If the ball carrier was driven backwards after the initial contact it was deemed to be negative offensive metres.
Offload	The ball-carrier is able to pass the ball to a teammate during the tackle [23].
Error	If during the process of a tackle event the ball carrier loses possession of the ball resulting in the defending team receiving possession of the ball it was deemed to be an error.

One analyst coded the variables for all 23 matches. This ensured consistency with the interpretation and coding of the game-specific definitions. Although only one analyst was used, it is expected that when using a human observer that there is a level of subjectivity.[99] The intra-coder reliability was determined by randomly selecting one match and analysing a second time. Coding for the same match was separated by 14 days. The intra-class correlation for test–retest reliability and typical error of measurement (TE) were calculated for order of contact ($r = 0.99$; $TE = 3.5\%$), height of tackle ($r = 0.99$, $TE = 2.2\%$), number of tackles ($r = 0.99$, $TE = 2.7\%$), dominant tackles ($r = 0.99$, $TE = 3.3\%$), missed tackles ($r = 0.98$, $TE = 3.0\%$), positive tackles ($r = 0.99$, $TE = 2.2\%$), offloads ($r = 1.00$, $TE = 0.0\%$), and errors ($r = 1.00$, $TE = 0.0\%$).

Due to the data not being normally distributed, non-parametric tests and magnitude based inferences were used. Spearman’s rank order correlation coefficients were used to determine the relationships among muscular strength and power, tackling ability and match-play tackling performance. After controlling for playing position, players were divided into “good tacklers” or “poor tacklers” based on the median split of the results of the standardised one-on-one tackling drill. Kruskal-Wallis test was used to establish statistical differences in the muscular strength and power, tackling ability, and match-play tackling performance between “good tacklers” and “poor tacklers”, and forwards and backs. The level of significance was set at $p \leq 0.05$. Differences in physiological variables and tackling ability between the “good tacklers” and “poor tacklers” groups were also compared using Cohen’s effect size (ES) statistic.[79] Effect sizes of <0.2 , $0.2-0.6$, $0.61-1.2$, $1.21-2.0$, and >2.0 were considered trivial, small, moderate, large, and very large, respectively.[80]

6.4 Results

Tackling ability was significantly associated with 1RM squat ($r_s = 0.71$; $p < 0.01$) and the proportion of dominate tackles performed during match-play ($r_s = 0.76$; $p < 0.01$). Tackling ability was significantly associated with the second player involved in a tackle ($r_s = 0.56$; $p = 0.03$) and the third or more players involved in a tackle ($r_s = 0.56$; $p = 0.03$). No tackle outcomes were significantly related to contact zones 1RM squat was significantly associated with the proportion of dominant tackles ($r_s = 0.64$; $p < 0.01$). Body mass was negatively related to the proportion of missed tackles ($r_s = -0.55$; $p = 0.03$). The relationships among anthropometric, tackle ability, muscular strength and power qualities, and match-play tackling performance are shown in Table 6.2.

There was a significant difference in tackling ability between the “good tacklers” group and the “poor tacklers” group ($p < 0.01$; $ES = 3.01$). “Good tacklers” maintained leg drive on contact ($ES = 1.70$) and had their centre of gravity forward of their base of support ($ES = 0.78$) more regularly than the “poor tacklers”. There were no significant differences in strength qualities between the “good” and “poor” tacklers. “Good tacklers” made a greater proportion of dominant tackles ($p < 0.01$; $ES = 2.10$), a smaller proportion of missed tackles ($p < 0.04$; $ES = 1.15$), and performed a smaller proportion tackles that allowed offloads ($p = 0.02$; $ES = 1.61$) than “poor tacklers”. The match-play tackling performance of “good” and “poor” tacklers is shown in Table 6.3.

Table 6.2. Relationship among anthropometric, strength and power qualities, tackling ability, and match-play tackling performance in semi-professional rugby league players. †

	Body Mass	1RM Squat	1RM Bench	Relative Squat	Relative Bench	CMJ	PPU	Tackle Ability
Tackle Ability	0.16	0.71**	0.09	0.34	-0.12	0.53	-0.23	1.00
Tackles	0.09	0.27	0.10	0.07	-0.02	-0.04	-0.15	0.20
Dominant	0.32	0.65**	0.23	0.14	-0.03	0.22	-0.02	0.63**
Positive	0.10	0.30	0.36	0.19	0.39	0.34	0.27	0.04
Miss	-0.55*	-0.23	-0.20	0.39	0.20	0.11	0.19	-0.37
Offload	-0.12	-0.32	0.15	0.07	0.33	0.00	-0.08	-0.45
Errors	-0.12	-0.39	-0.18	-0.19	-0.12	0.08	-0.43	0.02

Relative Squat = squat relative to body mass; Relative Bench = bench press relative to body mass; CMJ = counter movement jump peak power; PPU = plyometric push up peak power; Tackles = number of tackles per game; Dominant = proportion of dominant tackles; Positive = positive tackle; Miss = proportion of missed tackles; Offload = proportion of offloads conceded per game; Error = the proportion of errors forced each game.

† Data are reported as Spearman's rank order correlation coefficients, r_2 .

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

Table 6.3. Match-Play Tackling Performance of “Good” and “Poor” Tacklers†

	Good Tacklers	Poor Tacklers	Effect Size	Difference
Tackles	21.2 ± 7.7	15.0 ± 10.4	0.67	Moderate
1 st Player involved (%)	54.8 ± 10.9	64.3 ± 9.9	-0.91	Moderate
2 nd Player involved (%)	39.0 ± 7.6	33.6 ± 9.0	0.65	Moderate
3 rd + player involved (%)	11.4 ± 5.3*	5.9 ± 1.5	1.40	Large
Zone 1 (%)	0.3 ± 0.2	0.8 ± 1.0	-0.64	Moderate
Zone 2 (%)	10.8 ± 5.3	10.5 ± 7.9	0.05	Trivial
Zone 3 (%)	25.8 ± 7.8	21.5 ± 10.0	0.49	Small
Zone 4 (%)	67.7 ± 10.3	70.9 ± 14.7	-0.26	Small
Positive tackles (%)	4.1 ± 3.6	4.7 ± 3.7	-0.17	Trivial
Dominant tackles (%)	58.4 ± 6.8**	45.1 ± 5.9	2.10	Very Large
Missed tackles (%)	8.2 ± 2.8*	15.3 ± 8.3	1.15	Moderate
Offloads (%)	3.3 ± 1.3*	6.33 ± 2.4	1.61	Large
Errors (%)	3.3 ± 1.0	4.3 ± 2.2	0.54	Small

† Data are means ± SD. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61-1.2 = moderate; 1.21-2.0 = large; >2.0 = very large.

* Significant difference (p<0.05) between groups.

** Significant difference (p<0.01) between groups.

Forwards had significantly greater body mass ($p=0.03$; $ES=1.13$), and performed more tackles ($p=0.03$; $ES=1.49$) than backs. In addition, a smaller proportion, albeit not statistically significant, of forwards' tackles initiated contact between the knees and waist ($p=0.06$, $ES=1.31$), and a smaller proportion of their tackles were missed tackles ($p<0.01$; $ES=1.38$). Although not statistically significant, backs had a moderately higher proportion of their tackles concede offloads ($p=0.16$, $ES=0.84$) and tackles resulting in errors ($p=0.10$; $ES=1.00$).

6.5 Discussion

This study examined the influence of muscular strength and power, and tackling ability on match-play tackle performance in semi-professional rugby league players. Tackling ability (as measured using the standardised one-on-one tackle drill) was significantly related to the proportion of dominant tackles made during match-play. This finding is consistent with a previous study which found that tackling ability was significantly related to dominant tackles effected in professional rugby league matches [10]. However, unlike the previous research there was no significant relationship found between tackling ability and the proportion of missed tackles. Furthermore, other tackle outcomes, positive tackles, offloads, and errors were not significantly related to tackling ability.

The only muscular strength and power quality that was significantly related to tackling ability was 1RM squat. This finding is in partial agreement with previous research that found that 3RM squat, 3RM bench press, squat relative to body mass and PPU were significantly related to tackling ability [85]. Furthermore, 1RM squat was significantly associated with the proportion of dominant tackles made during match play. The results of this study suggest that lower-body strength plays a significant role in tackling ability

and match-play tackle performance at a semi-professional playing level, thus highlighting the importance of developing lower-body muscular strength in these players.

Lower-body power, as measured by CMJ was not significantly related to tackling ability. This finding is in agreement with a previous study that found that vertical jump performance was not significantly associated with tackling ability in sub-elite rugby league players [58]. However, it is in conflict with other studies that found a significant association between vertical jump performance and tackling ability in professional and elite junior rugby league players [14, 16]. A possible explanation for the lack of relationship between CMJ and tackling ability may be the lack of movement specificity of the test for lower-body power. A large component of tackling ability is the ability to produce high levels of horizontal leg drive to halt the forward progress of the attacking player. Maulder and Cronin [84] found that horizontal jump tests have stronger relationships to sprint ability than vertical jump tests, with the authors suggesting that their finding was due to the horizontal nature of sprinting which is not assessed by vertical jumping.

There was a very large difference in tackling ability between the “good tacklers” and the “poor tacklers”. The “good tacklers” had superior tackling ability because they maintained leg drive on contact and had their centre of gravity forward of their base of support more regularly than the “poor tacklers”. A significantly larger proportion of dominant tackles were made by the “good tacklers” compared to the “poor tacklers”, as well as a significantly smaller proportion of missed tackles and tackles that allowed an offload. Although the only tackle outcome that was significantly related to tackle ability was the proportion of dominant tackles it must be noted that players with good tackling

ability, as measured by a standardised tackling assessment, performed a larger proportion of dominant tackles, missed a lower proportion of tackles, and were involved in a lower proportion of tackles that allow offloads. Collectively, these findings further vindicate the use of the standardised one-on-one tackle drill for evaluating tackling ability in rugby league players.

Players in the “poor tacklers” group were involved in proportionally more tackle contests as the first player involved than the “good tacklers”. This data would suggest that either the “poor tacklers” are forced to perform one-on-one tackles due to their playing position or that they are targeted by the opposition due to their perceived poor tackling ability. From a practical perspective, players that have been identified as having poor tackling ability should be provided with additional coaching to improve tackling ability and special consideration should be made regarding which players defend next to each other in a match so that better defenders can assist poorer tacklers.

Forwards were involved in more tackles than backs, with backs missing a larger proportion of tackles, and conceding more offloads than forwards. Backs made a significantly greater proportion of their tackle attempts between the knees and the hips compared to forwards, which may suggest that the lower contact zone of backs may leave them vulnerable to players offloading in their tackles. Gabbett et al [10] suggested that backs are forced to engage in more one-on-one tackles due to their position in the defensive line and that this may cause these players to be involved in proportionately less dominant tackles than forwards. Although there was a moderate difference in the proportion of dominant tackles between forwards and backs, it was not statistically significant.

This study found that body mass was significantly related (negatively) to the proportion of missed tackles during rugby league match-play. This finding is in conflict with previous studies that found that body mass was not significantly related to tackling performance during match-play in adolescent rugby league players [33]. Furthermore, previous research examining tackling ability in amateur rugby league players found that lighter players had superior tackling ability, as measured using a standardised tackling assessment, than their heavier counterparts [13]. A possible explanation for the finding in this study might be that teams target their attack at lighter players to exploit possible size and momentum mismatches.

A limitation of this study was that tackling ability was only examined at the start of season. It is probable that the tackling ability of players changed throughout the season. Players with initially poor tackling ability may have elicited improvements in their tackle technique throughout the season. In contrast, due to the nature of contact sport, players may receive injuries which may inhibit their tackling ability. Future studies may examine if tackling ability changes over the course of a season and if those changes affect match-specific performance.

6.6 Practical Application

The findings in this study further vindicates the use of the standardised one-on-one tackling drill for evaluating tackling ability in rugby league players. Off-field tackling assessment provides practical utility in supplying information predictive of tackling performance in competition. Players identified as having poor tackling ability should be provided with additional coaching to improve tackling ability and special consideration

should be made regarding which players defend next to each other in a match so that better defenders can assist poorer tacklers.

The results of this study suggest that lower-body strength does contribute to effective tackling ability during both a standardised tackling assessment and match-play at a semi-professional playing level. Although a significant correlation does not suggest causation, this study highlights the importance of developing lower-body muscular strength in these players.

6.7 Conclusions

This is the first study to examine the tackling ability and in-game tackling performance of semi-professional rugby league players. Although tackling during a rugby league match involves team defensive structures and a decision-making component, the standardised one-on-one tackle drill has been shown to be a reliable and valid method to evaluate tackling ability. Furthermore, the findings of this study demonstrates that lower-body muscular strength contributes to tackling ability, as well as the proportion of dominant tackles made during match play.

Chapter 7: Tackle characteristics and outcomes in match-play rugby league: The relationship with tackle ability and physical qualities

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7.1 Abstract

This study examined tackle characteristics and their relationships with match-play tackle outcomes, tackling ability, and physical qualities in rugby league players. Fifteen semi-professional rugby league matches were analysed, with 2355 tackle events coded. Tackle characteristics such type of tackle, or evasive manoeuvre of ball carrier, as well as tackle outcomes such as missed or successful tackles were coded. Muscle strength and power tests, and a standardised assessment of tackling ability were performed in sixteen players. It was found that a medium body position, utilizing a shoulder or smother tackles, and producing leg drive upon contact decreased the odds of a missed tackle. Performing a front-on tackle, with a contact zone at the chest region reduced the odds of an offload. Tackling ability, as examined 'off-field', using a one-on-one tackle drill, was significantly related to defenders moving forward prior to contact ($r_s = 0.60$, 95% CI 0.15-0.85, $P = 0.02$), making a front-on tackle ($r_s = 0.53$, 95% CI 0.05-0.81, $P = 0.04$), and displaying medium body height ($r_s = 0.57$, 95% CI 0.10-0.83, $P = 0.02$) in match-play tackles. Lower-body strength was significantly related to defenders exhibiting a medium body position ($r_s = 0.60$, 95% CI 0.15-0.85, $P = 0.01$) and the ball-carrier being placed on their back ($r_s = 0.72$, 95% CI 0.35-0.90, $P = 0.002$). The results of this study suggest that match-play tackle performance is related to both tackle characteristics and physical qualities.

7.2 Introduction

The ability to control and dominate the tackle contest is one of the most important components for success in contact sports such as rugby league or rugby union [5, 32]. Successful teams concede fewer metres in defence and are involved in fewer ‘ineffective’ tackles than unsuccessful teams [32, 100]. Anecdotally, the ability to control the ruck (i.e. play-the-ball speed) is considered an important factor for rugby league success [5]. A greater understanding of tackle attributes and the physical qualities of players can influence tackling outcomes is critical from a performance perspective.

Previous research examining rugby league match-play tackles identified or characterised tackles by player position, direction in which contact is made and contact zone [21, 22]. King et al [21] reported that the hip and thigh or mid-torso region was the most common contact zone, with contact made most commonly from behind the visual field of the ball-carrier, and involving 2 or 3 defenders. Austin et al [22] found that the first defender was most likely to make a front-on tackle, either low or high, a second player generally performed a front-on high tackle, and if a third player became involved, their contact was most likely to be from the side and above the waist. Although these studies provide a good description of the most common tackle characteristics in rugby league match-play, they do not identify how these characteristics influence tackle outcomes such as successful, missed, or dominate tackles.

In previous research focusing on tackling ability, a standardised one-on-one tackling drill has been used to quantify tackle technique in rugby league players [10, 91]. At a professional level, players who demonstrated poor tackling ability missed more tackles during match-play than players with superior tackling ability [10]. Players with good

tackling ability were involved in a greater proportion of dominant tackles [10]. Similarly, semi-professional players with good tackling ability on a standardised proficiency test were involved in a greater proportion of dominant tackles and missed a smaller proportion of tackles during match-play [91]. These studies have highlighted the association between tackling technique and match-play performance however, the studies have not investigated whether this association is due to differences in tackle characteristics during match-play.

Lower- and upper-body muscular strength, as well as upper-body power have been shown to be significantly related to tackling ability, as quantified by a standardised one-on-one tackle test, in semi-professional rugby league players [85, 101]. Furthermore, greater lower-body strength as measured by maximal squat and lower-body power measured by a countermovement jump have been shown to be significantly associated with the proportion of dominant tackles made during match-play [15, 91]. Therefore, it appears that physiological factors influence tackle performance but the mechanisms or there associations with tackle characteristics are still unknown.

To date, the research examining tackling in rugby league has focused on the associations between tackling technique, and physiological attributes on tackle performance outcomes. To date, no research has examined how the aforementioned variables are related to match-play tackle characteristics. Therefore, the primary purpose of this study was to examine tackle characteristics and their relationships with match-play tackle outcomes. Secondly, this study examined a sub group of players to explore possible relationships between tackle characteristics, and tackle outcomes, tackling ability, and physical qualities.

7.3 Methods

Participants

For the match-play video analysis of this study, the tackle characteristics of 38 senior semi-professional rugby league players were coded. A subgroup of sixteen (mean \pm SD age, 24.7 ± 3.3 yrs; mass, 97.3 ± 8.1 kg) players participated in the strength and power testing, as well as the standardised one-on-one tackle drill. The players were categorised by playing position, with 4 middle forwards (prop and lock), 4 wide running forwards (second rower), 3 adjustables (hookers, halfbacks and five-eighths) and 5 outside backs (centres, wingers, and fullbacks). All players were from the same rugby league club. Players were classified as semi-professional as they received remuneration for playing rugby league but also relied on other forms of income. Players were free from injury at the commencement of the study. All players received a detailed explanation of the study, including information on the risks and benefits. Written informed consent was obtained from the subgroup of 16 participants before the start of the study. All the procedures were approved by the Australian Catholic University Ethics Committee (2013 01Q) prior to data collection.

Strength and Power Testing

To minimise the effect of fatigue, the strength and power tests were conducted 72 hours after any previous training sessions and players were instructed to refrain from strenuous exercise prior to the testing session. One repetition maximum (1RM) bench press and back squat tests were used to assess upper- and lower-body muscular strength. Under the guidance of a strength and conditioning specialist, players performed increasingly heavier loads using a standard 20 kg Olympic barbell, with 3 to 5 minutes rest between sets, until they attempted a load that they could lift only once with appropriate form and technique.

For the back squats, players were required to perform the movement to a below parallel thigh position (i.e. they descended to a position where the hip crease passed below the middle of the knee joint) and for the bench press it was essential for the bar to touch the chest before the ascending phase. The intraclass correlation coefficients for test-retest reliability and typical error of measurement were 0.98 and 2.8% for the 1RM bench press and, 0.96 and 3.0% for the 1RM squat. Relative upper- and lower-body strength were calculated by dividing the 1RM of the bench press and squat by the player's body mass [102].

A countermovement jump (CMJ) and plyometric push-up (PPU) were performed on a force platform (Kistler 9290AD Force Platform, Kistler, Switzerland) to quantify lower- and upper-body peak power, respectively. The CMJ was performed with hands on hips and the PPU was performed from a standard push up position with arms fully extended. When indicated, the players dipped to a self-selected depth before explosively jumping or pushing as high as possible off the platform. Players had two attempts with approximately 2 minutes recovery between each effort; their highest power output was used for analysis. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for CMJ peak power were 0.81 and 3.5%, respectively, and for the plyometric push-up were 0.97 and 3.8%, respectively.

Standardised One-on-one Tackle Drill

The video analysis of a standardised 1-on-1 tackle drill has been used to examine tackling ability in previous studies [13, 14, 16]. The drill was conducted with two players of similar stature and body mass, a defender and a ball carrier, 10 metres apart. Three video cameras (Sony AX100, Sony, Japan) were set up on the right, left and rear of the drill.

The participants performed six consecutive tackles, three on the right shoulder and three on the left shoulder. The participants were instructed to run directly at each other (the ball carrier was to make no evasive actions) so that the initial contact was made at approximately the 5 metre mark. The drill was performed while the players were in a non-fatigued state at the start of a training session. Tackling ability was assessed by one analyst using the same standardised technical criteria that have been used in previous research [13, 14, 16]. The players were aware of the technical criteria used to assess tackle ability and they were the same coaching cues used during skill training sessions.

The technical criteria included:

1. Contact made at the centre of gravity of the ball-carrier
2. Initial contact made with the shoulder
3. Body position square and aligned
4. Leg drive upon contact
5. Watch the target onto the shoulder
6. Centre of gravity forward of the base of support

Each tackle received a score out of 6. Players were awarded 1 point for each criteria they achieved or 0 points if they failed to meet the criteria while performing a tackle. The players received an aggregate score (arbitrary units) from all 6 tackles, which was then converted to a percentage. The analyst was able to use all three camera angles and manipulate the speed of the footage. Each tackle was analysed a second time 28 days later to examine the test-retest reliability. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for tackling ability were 0.88 and 3.9%, respectively.

Match-play Analysis

Fifteen semi-professional rugby league matches played in the 2015 season were analysed from video recordings. Tackle characteristics of the first player involved in every tackle contest were coded using Dartfish (Premium version for Windows, Dartfish, Switzerland). Furthermore the Consistent with previous research examining the tackle contest, characteristics were recorded in three distinct phases [23, 103]; pre-contact (0.5 s prior to initial contact), contact (first instance of contact), and post-contact (ruck and outcomes). Tackle outcomes were also coded, this included successful tackles, missed tackles, tackles that allowed an offload and dominate tackles. Tackle characteristics and outcomes definitions for each of the phases were guided from previous research conducted in this area [21, 23, 78, 104]. Definitions of the tackle characteristics and outcomes examined in this study are shown in Table 7.1.

Table 7.1. Definitions for tackle characteristics, outcomes

Tackle variable	Definitions
Pre-contact Phase	
Position of ball carrier and tackler	
Middle forward	Prop and lock
Wide running	Second row
Forward	
Adjustable	Hooker, halfback and five-eighth
Outside Back	Centre, winger and fullback
Body position	
Upright	Tackler exhibited high body height with knees and hips extended
Medium	Tackler exhibited moderate flexion at hips and knee
Low	Tackler exhibited low body height
Direction of movement of tackler	
Forward	Towards the opposition try line
Backwards	Moving towards own try line
Lateral	Towards the touchline (across the field)
Orientation of the tackler in relation to ball-carrier	
Front on	Tackler and ball-carrier face to face
Side	Tackler moving in from the ball-carrier's side
Oblique	Tackler moving into ball-carrier at an angle
Behind	Tackler chasing ball-carrier towards own try-line
Evasive action of ball-carrier	
Straight	Ball-carrier ran straight at the defence
Side step	Ball carrier performed an evasive step initiated by either leg
Arcing run	Ball-carrier performed an arcing run
Lateral	Ball-carrier ran towards the side line
Diagonal run	Ball-carrier ran at an angle
Contact Phase	
Fend	
Absent	Ball-carrier provided no fend
Present	Ball-carrier provides a fend
Direction of tackle	
Front	Tackler makes contact in front of ball-carrier
Side	Tackler makes contact with the ball-carrier's side
Oblique	Tackler makes contact with ball-carrier at an angle
Behind	Tackler makes contact with the ball-carrier from behind
Type of tackle	
Smother tackle	Tackler uses chest and wraps both arms around ball-carrier
Shoulder tackle	Tackler makes initial contact on the ball-carrier with the shoulder
Arm tackle	Tackler impedes ball-carrier with initial arms contact
Jersey tackle	Tackler holds ball-carrier's jersey
Tap tackle	Tackler trips ball-carrier with hand on lower limb

Contact zone	
Lower Legs	Below the player's knees
Hip and thigh	From the player's hip to the knee
Torso	From the bottom of the player's hips to the player's ribs
Chest	From the level of the ribs to the shoulders
Head	Head
Leg drive	
Absent	No leg drive on contact
Present	Moderate knee movement on contact
Post-contact Phase	
Tackled position of ball-carrier	
Back	Tackle is completed with ball-carrier on their back
Front	Tackle is completed with ball-carrier on their stomach
Side	Tackle is completed with ball-carrier on their side
Kneeling	Tackle is completed with the ball-carrier on their knees
Standing	Tackle is completed with the ball-carrier standing
Tackle performance outcomes	
Missed tackle	Any unsuccessful attempt to complete a tackle where the tackler/defender has made contact with the ball-carrier and they have broken from the tackle before it was completed
Offload	The ball-carrier is able to pass the ball to a teammate during the tackle
Dominant tackle	A tackle was deemed to be dominant if the time from when the ball-carrier's forward momentum has been halted to when the ball touches the foot during the play-the-ball exceeded four seconds or the tackle resulted in an offensive error

Definitions adapted from [21, 23, 78, 104]

A total of 2355 tackle involvements were examined. The 16 participants in the study made up 1327 of these tackles. The participants competed in an average of 10 games (range: 4 to 15) and were involved in an average of 9 tackle events per match (range: 2 to 17). The same analyst who assessed the standardised one-on-one tackling ability test also coded the variables for all 15 matches. This ensured consistency with the interpretation and coding of the game-specific definitions. Although only one analyst was used, it is anticipated that when using a human observer that there is a level of subjectivity [99]. The intra-coder reliability was determined by randomly selecting one match and analysing a second time. Coding for the same match was separated by 21 days. Cohen's Kappa coefficient (κ) was used to evaluate the intra-reliability of the coder [105]. All variables had a kappa statistic of 0.92 or greater. A kappa statistic between 0.81 to 0.99 represents an "almost perfect" agreement between repeated measures [99, 105].

Statistical Analysis

All data was analysed using SPSS (version 23 for Windows, SPSS Inc., USA). A multinomial logistic regression was used to determine the relationships between tackle outcomes and tackle characteristics. Prior to the multinomial logistic regression analysis, descriptive statistics were examined and tackle characteristics with a frequency of 0% were omitted from the analysis. The analysis was run in two stages. Firstly, tackle variables were associated singularly to tackle outcomes. Secondly, an adjusted model, which included only significant ($P < 0.05$) tackle variables, was run including tackle outcomes. Non-significant variables were omitted from the second model. Odds ratios (OR) and 95% confidence interval (CI) were reported. Logistic regression requires variables to be calculated and compared against a reference variable. There was no specific method for the selection of the reference variable.

Spearman's rank order correlation coefficients were used to determine the relationships among muscular strength and power, tackling ability and match-play tackling characteristics and outcomes. Due to the data not being normally distributed, non-parametric tests and magnitude based inferences were used. Data were reported as Spearman's rank correlation coefficients (r_s) and 95% confidence intervals (CI). After controlling for playing position, with each group receiving an equal number of forwards and backs, players were divided into "good tacklers" (25.0 ± 4.5 yr; 98.8 ± 6.0 kg) or "poor tacklers" (24.4 ± 3.8 yr; 95.7 ± 10.0 kg) based on the median split of the results of the standardised one-on-one tackling drill. Kruskal-Wallis test was used to establish statistical differences in the muscular strength and power, tackling ability, and match-play tackling performance between "good tacklers" and "poor tacklers". The level of significance was set at $P \leq 0.05$. Differences in physiological variables and tackling ability between the "good tacklers" and "poor tacklers" groups were also compared using Cohen's effect size (ES) statistic [79]. Effect sizes of <0.2 , $0.2-0.6$, $0.61-1.2$, $1.21-2.0$, and >2.0 were considered trivial, small, moderate, large, and very large, respectively [106].

7.4 Results

Missed Tackles

The relationships between tackle characteristics and missed tackles are shown in Table 7.2. When carrying the ball, the odds of adjustables (OR 1.91, 95% CI 1.16-2.15, $P = 0.01$) breaking a tackle were 1.9 times greater than the other playing positions. Wide running forwards (OR 0.47, 95% CI 0.28-0.79, $P = 0.004$) were least likely to miss a tackle. A side step (OR 1.86, 95% CI 1.30-2.64, $P < 0.001$) or lateral (OR 2.53, 95% CI 1.50-4.27, $P < 0.001$) evasive movement by the ball-carrier significantly increased the

odds of a missed tackle. The odds of a missed tackle increased 4-fold when the ball-carrier produced a fend (OR 4.04, 95% CI 2.83-5.78, $P < 0.001$). A medium body position by the defender decreased the odds of a missed tackle. Arm (OR 3.36, 95% CI 2.13-5.29, $P < 0.001$) and jersey (OR 2.25, 95% CI 1.17-4.32, $P = 0.02$) tackles increased the chances of a missed tackle compared to a smother tackle. An absence of leg drive (OR 2.53, 95% CI 1.30-4.91, $P = 0.006$) by the tackler increased the odds of a missed tackle.

Table 7.2. Multinomial logistic regression for tackle characteristics and missed tackles

	OR	95% CI
Pre-contact phase		
Playing position of ball-carrier (Middle Forwards)		
Wide running Forwards	1.06	0.64-1.77
Adjustables	1.91	1.16-2.15*
Outside Backs	0.98	0.64-1.49
Playing position of defender (Middle Forwards)		
Wide running Forwards	0.47	0.28-0.79**
Adjustables	0.68	0.46-1.01
Outside Backs	1.22	0.80-1.85
Body position (High)		
Low	1.07	0.70-1.63
Medium	0.63	0.43-94*
Evasive action by ball carrier (run Straight)		
Side step	1.86	1.30-2.64**
Arcing run	1.13	0.53-2.40
Lateral	2.53	1.50-4.27**
Diagonal run	1.05	0.477-2.32
Contact phase		
Fend (Fend absent)		
Fend	4.04	2.83-5.78**
Type (Smother)		
Shoulder	0.92	0.45-1.88
Arm	3.36	2.13-5.29**
Jersey	2.25	1.17-4.32*
Leg drive (Present)		
Absent	2.53	1.30-4.91**

OR = Odds Ratio; CI = Confidence Interval

Reference variable in parentheses

* $p \leq 0.05$; ** ≤ 0.01

Offloads

Lateral evasive action (OR 1.90, 95% CI 1.09-3.33, $P = 0.02$) or the use of a fend by the ball-carrier (OR 1.91, 95% CI 1.24-2.96, $P = 0.003$) increased the odds of an offload. A front-on tackle decreased the odds of an offload compared to a tackle that was side-on (OR 1.64, 95% CI 1.06-2.54, $P = 0.03$), oblique (OR 1.55, 95% CI 1.00-2.43, $P = 0.05$) or from behind (OR 2.33, 95% CI 1.28-4.25, $P < 0.006$). Furthermore, when the initial contact was made at the hip and thighs (OR 2.45, 95% CI 1.50-4.02, $P < 0.001$) or torso (OR 2.97, 95% CI 2.06-4.27, $P < 0.001$) the odds of an offload increased compared to contact made on the chest (Table 7.3).

Table 7.3. Multinomial logistic regression for tackle characteristics and offloads

	OR	95% CI
Pre-contact phase		
Evasive action by ball-carrier (run Straight)		
Side step	1.42	0.70 – 2.07
Arcing run	0.45	0.14-1.46
Lateral	1.90	1.09-3.33*
Diagonal run	0.53	0.16-1.73
Contact phase		
Fend (Fend absent)		
Fend	1.91	1.24-2.96**
Direction of tackle (Front on)		
Side on	1.64	1.06-2.54*
Oblique	1.55	1.00-2.43*
Behind	2.33	1.28-4.25**
Zone (Chest)		
Hip and thigh	2.45	1.50-4.02**
Torso	2.97	2.06-4.27**

OR = Odds Ratio; CI = Confidence Interval

Reference variable in parentheses

* $p \leq 0.05$; ** ≤ 0.01

Dominant Tackles

No pre-contact or contact tackle characteristics were significantly associated with dominant tackles. The position of the tackled player was the only variable associated with dominant tackles. The odds of a dominant tackle were increased when the ball-carrier was placed on their side (OR 2.04, 95% CI 1.52-2.75, $P < 0.001$) or on their back (OR 3.83, 95% CI 2.91-5.05, $P < 0.001$).

Tackling Ability

Tackling ability (measured in the standardised off-field assessment) was negatively associated with the proportion of missed tackles ($r_s = -0.66$, 95% CI -0.87- -0.25, $P = 0.006$). Tackling ability was positively related to the defender moving forward ($r_s = 0.60$, 95% CI 0.15-0.85, $P = 0.02$) prior to contact, making a front-on tackle ($r_s = 0.53$, 95% CI 0.05-0.81, $P = 0.04$), and displaying medium body height ($r_s = 0.57$, 95% CI 0.10-0.83, $P = 0.02$). Tackling ability was negatively associated with lateral movement of the defender ($r_s = -0.52$, 95% CI -0.83- -0.10, $P = 0.04$) prior to contact, and direction of the tackle from behind ($r_s = -0.50$, 95% CI -0.80- -0.01, $P = 0.05$).

Muscular Strength and Power

Tackling ability was significantly related to 1RM squat ($r_s = 0.54$, 95% CI 0.06-0.82, $P = 0.03$) and squat relative to body mass ($r_s = 0.55$, 95% CI 0.08-0.82, $P = 0.03$). 1RM squat was significantly related to medium body position ($r_s = 0.60$, 95% CI 0.15-0.85, $P = 0.01$) and the tackled position of the ball-carrier being on their back ($r_s = 0.72$, 95% CI 0.35-0.90, $P = 0.002$). Bench press relative to body mass was significantly associated with the tackled position of the ball-carrier being on their side ($r_s = 0.52$, 95% CI 0.03-0.81, $P = 0.04$). The plyometric push up was significantly related to a high body position ($r_s = 0.63$,

95% CI 0.20-0.86 $P = 0.01$) and contact on the chest ($r_s = 0.60$, 95% CI 0.15-0.84, $P = 0.01$) of the ball-carrier.

Good vs. Poor Tacklers

Tackling ability of the “good” and “poor” tacklers is shown in Table 7.4. There was a significant difference in tackling ability between the good tacklers group and the poor tacklers ($76.0\% \pm 7.5\%$ vs $64.2\% \pm 6.8\%$, $P < .01$; ES = 1.61). There were no significant differences in strength qualities between the “good” and “poor” tacklers.

Table 7.4. Standardised Tackling Ability Test of “Good” and “Poor” Tacklers

	Good (n = 8)	Poor (n = 8)	Effect Size
Tackle ability (%)	75.7 ± 7.5**	64.2 ± 6.8	1.61
Contact Centre of gravity (AU)	5.9 ± 0.4	4.9 ± 2.1	0.66
Initial contact with shoulder (AU)	5.9 ± 0.4	5.4 ± 1.2	0.57
Square and aligned (AU)	2.6 ± 1.5	1.6 ± 1.6	0.64
Leg drive on contact (AU)	4.3 ± 2.1	4.4 ± 1.2	-0.07
Watch target onto shoulder (AU)	2.6 ± 2.3	1.3 ± 1.8	0.68
Centre of gravity over base of support (AU)	6.0 ± 0.0	5.6 ± 0.7	0.71

Data are means ± SD. Tackle ability score presented as a percentage. Each variable represents a score of a possible score of 6 (ie. The sum of 6 trials). Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

** Significant at p<0.01.

“Good tacklers” performed a smaller proportion of tackles that allowed offloads ($P = 0.04$; $ES = -1.03$). Although not statistically significant, “good” tacklers performed proportionally more dominant tackles ($P = 0.17$; $ES = 0.80$) and fewer missed tackles ($P = 0.15$; $ES = -0.86$) than “poor” tacklers.

7.5 Discussion

The purpose of this research was to examine the associations between individual player qualities, match-play tackle characteristics, and tackle outcomes. Similar to research examining rugby union match-play tackle characteristics, this study found that the type of tackle and leg drive were significant predictors of successful tackle outcomes [23]. Smother and shoulder tackle types reduced the likelihood of a missed tackle compared to arm or jersey tackles. Similarly, absence of leg drive by the defender upon contact increased the odds of a missed tackle by 2.5 times. The body position of the defender was also a significant predictor of missed tackles. A medium body position of the defender significantly decreased the odds of a missed tackle compared to a high or low body position. These results support the technical criteria used to assess tackling ability in the standardised one-on-one tackle drill in this study and previous research; specifically contacting the target with the shoulder, leg drive upon contact and centre of gravity over the base of support [14, 16, 85, 91].

In this study the contact zone was not a significant predictor of missed tackles but it predicted the capacity to prevent an offload. When the tackle contact was initiated in the chest and shoulder region, the odds of an offload greatly diminished. These findings are consistent with Hendricks et al [23] who found that low contact increased the probability of an offload. Furthermore, the likelihood of an offload was greatly reduced when contact

was made front-on rather than side-on, oblique or from behind. These results are expected, as contact made in the chest and shoulder region and front-on would suggest that the defender has made an attempt to impede the ball-carrier's ability to pass the football.

The actions of the ball-carrier significantly influenced tackle outcomes. A fend by the ball-carrier increased the odds of the defender missing the tackle or allowing an offload. Similar results were reported in a study examining tackle breaks in rugby union which found that fending strategies were significantly associated with tackle breaks and offloads [103]. The evasive action of the ball-carrier also influenced the odds of tackle outcomes. When the ball-carrier used a side-step or lateral evasive movement prior to contact the odds of a missed tackle increased by 1.8 and 2.6 times, respectively. Collectively, these results suggest that evasive and fending strategies by the ball-carrier increase the odds of breaking a tackle. Exposure to these attacking strategies in training drills may increase players' ability to make successful tackles during match-play.

Tackling ability as assessed through the standardised one-on-one tackling drill was negatively associated with the proportion of missed tackles. These results are in agreement with previous research which also found associations between tackling ability and missed tackles [10, 91]. Furthermore, tackling ability was positively associated with defenders moving forward prior to contact, making contact front-on and exhibiting medium body position. Tackling ability was negatively associated with lateral movement prior to contact and contact from behind. These results further vindicate the use of the standardised one-on-one tackle drill for evaluating tackling ability. However, it must be noted that tackling ability was not significantly associated with the proportion of tackles

that resulted in an offload. There are two parts to a successful tackle; the first is stopping the forward progress of the ball carrier, the second is stopping the promotion of the football. It is possible that the standardised one-on-one tackling drill used in this study, where contact is made at the torso, does not evaluate a players' ability to prevent an offload during match-play. It may be of value for future studies to examine alternative tackling drills.

Consistent with previous research, players in the “good tackler” group had a larger proportion of dominant tackles, and a smaller proportion of missed tackles and offloads than the “poor tackler” group [91]. Surprisingly, there was no significant difference in tackle characteristics between the two groups. Given that the “good” and “poor” tackling groups were controlled for playing position (equal number of forwards and backs), it is possible that match-play tackle characteristics is influenced by position specific situations. Previous research examining tackling in rugby league match-play found that backs were more likely to be involved in one-on-one tackle contests, and were more likely to sprint 10 to 20 metres into their tackles [22]. Even though “good” tacklers make proportionally fewer unsuccessful tackles, a difference in tackle characteristics to achieve positive tackle outcomes may vary based on playing position. We recommend that future research investigate the differences in tackle characteristics among the different playing positions.

In this study both absolute and relative lower-body strength were significantly associated with tackling ability as assessed by the standardised one-on-one tackle test. These findings are in agreement with other research in this field [85, 91, 92]. Absolute lower-body strength was also found to be significantly associated with defenders presenting a

medium body position, suggesting that a medium body position is optimal for the transference of lower-body strength in the skill of tackling.

Interestingly, no pre-contact or contact tackle characteristics were associated with the dominant tackle outcome. The ball-carrier being put on their side or back were the only characteristics that were related to dominant tackles. This result is to be expected given it is inherently more difficult for the ball-carrier to get to their feet from these positions. Absolute lower-body strength and relative upper-body strength were significantly related to the ball-carrier being placed on their back and side, respectively. The results of this study suggest that factors after the initial contact, such as wrestling, may be more influential in achieving dominant tackle outcomes, and high levels of muscular strength would appear advantageous for controlling the tackle contest after the initial contact.

A limitation of this study is that the data and participants were all from the one club, thus team tactics, playing styles and individual playing ability may influence some of the findings in this study. We recommend that future research examine tackle characteristics and outcomes across several clubs.

An enhanced understanding of the elements that underpin match-play tackle performance will assist coaches in the development of skill-specific drills and the prescription of training. The results of this study suggest that match-play tackle performance is related to both tackle characteristics and physical qualities. This study has found that a medium body position, using a shoulder or smother tackle, and producing leg drive upon contact are key tackle characteristics associated with successful tackles, while producing a front-on tackle, with a contact zone at the chest region appears to be important in limiting

offloads. Based on the findings in this study it recommended that coaches emphasize the fore-mentioned tackle characteristics in training drills to improve tackle proficiency and educate players on how certain tackle characteristics affect tackle outcomes. Lower-body strength was found to be associated with defenders initiating contact in a medium body position and the ball-carrier placed on their back in a tackle. These findings are consistent with previous research finding that absolute lower-body strength was significantly related to tackle performance [85, 91, 101]. Collectively, the findings of these studies suggest that lower-body strength is an important element in tackling ability and therefore should be a major focus of rugby league strength and conditioning programming.

Chapter 8: An alternate test of tackling ability in rugby league players

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8.1 Abstract

This study investigated the relationship between two tests of tackling ability, muscular strength and power in semi-professional rugby league players. Thirty-one players, 19 first grade and 12 second grade underwent tests of muscular strength (1 repetition maximum bench press, chin-up, and squat) and power (plyometric push-up and countermovement jump). Tackling ability was assessed via video analysis of under-the-ball and over-the-ball tackle drills. The first grade players had significantly greater scores in both the under-the-ball ($P = 0.03$, ES = 0.84, 95% CI 0.07-1.50) and over-the-ball tackling ability tests ($P < 0.001$, Effect size (ES) = 1.86, 95% CI 0.83-2.52) compared to the second grade players. A large, significant relationship was found between under-the-ball and over-the-ball tackling ability ($r = 0.55$, 95% CI 0.24-0.76, $P = 0.001$). Lower-body strength ($r = 0.37$, 95% CI 0.02-0.64, $P = 0.04$) was moderately associated with under-the-ball tackling ability, whereas over-the-ball tackling ability was moderately associated with plyometric push up performance ($r = 0.39$, 95% CI 0.04-0.65, $P = 0.03$). This study found that over-the-ball tackling ability was significantly associated with under-the-ball tackling in semi-professional rugby league players. Furthermore, it was also found that compared to the second grade players the first grade players had superior tackle ability in both tackle drills. In this study it was observed that plyometric push up peak power was significantly related to over-the-ball tackling ability and absolute lower-body strength was associated with under-the-ball tackling ability. These findings provide skill coaches and strength and conditioning staff a greater understanding of elements that contribute to effective tackling ability.

8.2 Introduction

The ability to execute proficient and effective tackles is a critical skill for success in collision sports such as rugby league or rugby union [5, 32]. Recent studies have suggested that proficient tackle ability may play a role in the prevention of injury and concussions [47, 48]. Furthermore it has been shown that winning teams concede fewer metres in defence and are involved in fewer ‘ineffective’ tackles than losing teams [32, 100]. Previous research examining tackling ability through the analysis of a standardised one-on-one tackling drill, where contact is made at the torso of the ball-carrier, has been used to quantify tackle technique in rugby league players [10, 51, 91]. At a professional and semi-professional level, players who demonstrated superior tackling ability missed a smaller proportion of tackles and performed a greater proportion of dominant tackles during match-play than players with poor tackling ability [10, 91].

A study documenting tackle characteristics in the 2008 Australian National Rugby League competition found that the majority of tackles were performed at the mid torso of the ball-carrier [21]. However, a more recent study investigating tackling ability in semi-professional rugby league match-play found that approximately 70% of tackles were executed around the ball-carriers chest and shoulders and less than 25% of tackles were made at the torso region [91]. A reason for the change in tackle height may be due to an increased priority placed on players to stop the ball-carrier passing or off-loading the football. The likelihood of an offload is decreased when the initial contact zone was at the chest and shoulders compared to contact at the torso or legs [23]. Tackles made at the shoulder and chest region are commonly referred to as “over-the-ball” or “smother tackles”. It has been found that the smother tackle was as likely to have successful outcomes in rugby league and rugby union match-play compared to the traditional

shoulder tackle [23, 107]. A player's ability to perform a traditional shoulder tackle may not reflect their ability to tackle over-the-ball and given the high frequency of over-the-ball tackles, it appears important to assess this ability in a specific drill to determine whether it is a distinct skill to under-the-ball tackles.

Several studies have examined the physiological and anthropometric correlates of tackling ability in sub-elite and professional rugby league players [13, 14, 16, 85]. Well-developed acceleration (over a 10-metre sprint) and lower-body muscular power were associated with superior tackling ability in elite junior and professional rugby league players [13, 14, 16]. Furthermore, maximal squat and bench press as well as peak power of a plyometric push up have been shown to be significantly related to tackling ability in semi-professional rugby league players [85]. Existing research investigating tackling ability in rugby league have only used a standardised one-on-one tackle drill where contact is made under-the-ball of the ball-carrier. Given that the majority of the tackles made in match-play are over-the-ball tackles an investigation into the physiological correlates of an alternate tackling ability drill is warranted.

The purpose of this study was to investigate an alternate one-on-one tackling drill where contact is made at the chest and shoulder region of the ball-carrier (i.e. an over-the-ball tackle). This study i) compared the results between the under-the-ball and the over-the-ball tackle drill; ii) compared tackling abilities between higher- and lower-skilled rugby league players; and iii) investigated the relationship between muscular strength and power qualities and tackling ability in both drills.

8.3 Methods

Participants

Thirty-one semi-professional rugby league players (mean \pm SD age, 23.4 ± 2.2 yr; mass 95.6 ± 12.8 kg) participated in this study. All players were from one rugby league club; first grade players ($n = 19$; 23.4 ± 2.1 yr; 100.2 ± 11.9 kg) competed in a state level competition and second grade players ($n = 12$; 23.3 ± 2.5 yr; 88.5 ± 11.2 kg) competed in a metropolitan competition. Although there were different numbers of participants in the first grade and second grade groups, each group had similar proportions of props, backrowers, adjustables, and outside backs. Players were classified as semi-professional as they received remuneration for playing rugby league but also relied on other forms of income. The first grade and second grade players trained as one squad with all players completing 3 training sessions per week, with all sessions containing elements of resistance training, aerobic and anaerobic conditioning, as well as rugby league specific drills. All participants were free from injury and mid-way through a fifteen week preseason training program when they undertook muscular strength and power testing, and tackling assessments. All players received a detailed explanation of the study, including information on the risks and benefits, and written informed consent was obtained before data collection. All procedures were approved by the Australian Catholic University Ethics Committee (2013 01Q).

Experimental Design

The current study used a cross-sectional experimental design. The tests were conducted over the course of two sessions. The standardised one-on-one tackle drills were conducted on the first session. The power and strength data was collected at the second training session approximately 56 hours after the tackling ability tests. All players were familiar

with the testing protocols as they were part of their routine training testing. The players were instructed to be adequately hydrated prior to the sessions and to refrain from excessive exercise before the testing sessions.

Methodology

Tackling ability was examined in two tests; an under-the-ball drill and an over-the-ball drill. Both drills were conducted in a 10 metre grid with video cameras (Sony AX100, Sony, Japan) positioned on the left, right and rear of the drills. The protocol for the tackle drills were the same as previous research examining tackle ability in rugby league players [10, 16, 91]. In both drills participants performed six consecutive tackles, three on their right side and three on the left side, on another participant of similar height and mass. The participants were instructed to run directly at each other (the ball carrier was to make no evasive actions) so that the initial contact was made at approximately the 5 metre mark of the grid. The players were instructed to walk back to the start position after each tackle, allowing approximately 30 seconds between each tackle to minimise the fatigue. A randomised-counterbalanced design was used whereby sixteen players performed the under-the-ball tackling drill first and then performed the over-the-ball drill following a 30 minute break. The other 15 players performed the two tackle drills in the reverse order.

The criterion used to assess the under-the-ball drill was the same used to examine tackling ability through the video analysis of a standardised 1-on-1 defensive drill in previous studies [13, 14, 16]. The technical criteria for assessing the over-the-ball drill was developed through the collaboration of two expert rugby league coaches and were the same cues used during defensive drills at training. The criteria used for the assessment of the two drills are shown in Figure 8.1a and 8.1b.



Figure 8.1a. Under-the-ball tackle criteria

i) Contact made at the centre of gravity of the ball-carrier; ii) initial contact made with the shoulder; iii) body position square and aligned; iv) leg drive upon contact; v) watch the target onto the shoulder; vi) centre of gravity forward to the base of support



Figure 8.1b. Over-the-ball tackle criteria

i) Contact made on the ball; ii) initial contact made with the shoulder or chest; iii) body position square and aligned; iv) leg drive upon contact; v) watch the target into contact; vi) actively minimise space between the ball carrier's head, hips and feet

The technical criteria used to assess the one-on-one tackle drills examined key points.

The first criterion examined the contact zone of the tackle, the mid-section for the under-the-ball tackle and on the ball for the over-the-ball tackle. The second criterion examined the body part that the tackler used to initiate the contact, shoulder with the under-the-ball tackle and shoulder or chest in the over-the-ball tackle. A common flaw is for the tackler to initiate contact with their arm. The third criterion assessed if the tackler maintained a square and aligned body position during the tackle. During a tackle it is common for a tackler to twist their body to one side. The ability of the defender to maintain leg drive

upon contact was also examined. Through video analysis it can be observed if a player is able to maintain leg drive or plants their feet on the initiation of contact. The fifth criterion examined a player's ability to watch the target into contact rather than turning their head away prior to contact. The final criteria examined the body position of tackler in both drills. In the under-the-ball tackle drill it is critical for a player to make contact with their centre of mass in front of their base of support rather than over the base of support. In the over-the-ball tackle it is an important coaching cue for the player to actively minimise space between themselves and the ball carrier. It is a common flaw for a defender to move their body away from the tackler after contact.

One analyst assessed the tackling ability of both drills using Dartfish video analysis software (Premium version for Windows, Dartfish, Switzerland). Each tackle received a score out of 6. Players were awarded 1 point for each criterion they achieved while performing a tackle, or 0 points if they failed to meet the criteria. The players received an aggregate score (arbitrary units) from all 6 tackles in each drill, which was then converted to a percentage. To examine test-retest reliability of the video analysis of the tackle drills the analyst reassessed the tackle video 21 days after the initial analysis. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the under-the-ball tackle were 0.88 and 3.9%, respectively. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the over-the-ball tackle were 0.93 and 1.5%, respectively.

A countermovement jump (CMJ) and plyometric push-up (PPU) were performed on a force platform (Kistler 9290AD Force Platform, Kistler, Switzerland). The protocols to examine peak power are the same as used in previous research [85, 108]. The CMJ was

performed with hands on hips and the PPU was performed from a standard push-up position with arms fully extended. When instructed, the players descended to a self-selected depth before explosively jumping or pushing as high as possible off the platform. Players had two attempts with approximately a 2 minute recovery between each effort; their highest power output was used for analysis. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for CMJ peak power were 0.81 and 3.5%, respectively, and for the plyometric push-up were 0.97 and 3.8%, respectively. The peak power assessed by the PPU has been shown to a highly reliable test, however it should be noted that the concurrent validity of this assessment is yet to be examined [109]. To minimise the effect of fatigue, the strength and power tests were conducted 72 hours after any previous training sessions and players were instructed to refrain from strenuous exercise prior to the testing session.

Under the guidance of a strength and conditioning specialist, a one repetition maximum (1RM) bench press and chin-up were used to assess upper-body strength and the squat to test lower-body strength. The 1RM strength testing protocols were conducted in accordance to the Australian National Protocols for the Assessment of Strength and Power [110]. All players performed the 1RM squat test first, followed by the 1RM bench press, and lastly the 1RM weighted chin-up. For the squat and bench press, players performed increasingly heavier loads using a standard 20 kg Olympic barbell, with a minimum of 3 minutes rest between sets, until they attempted a load that they could lift only once with appropriate form and technique. For the back squats, players were required to perform the movement to a below parallel thigh position (i.e. they descended to a position where the hip crease passed below the middle of the knee joint) and for the bench press it was essential for the bar to touch the chest before the ascending phase.

The same loading protocols were used for assessment of the 1RM weighted chin-up. The 1RM weighted chin-up was calculated by adding the body mass of the player to the additional mass added to the player via a belt. Players were required to perform a supinated grip chin-up starting with arms fully extended. An attempt was deemed successful if the player was able to pull their body upwards until their chin, with their head in a neutral position, was over the bar. The intraclass correlation coefficients for test-retest reliability and typical error of measurement were 0.98 and 2.8% for the 1RM bench press, 0.98 and 2.7% for the 1RM chin-up and, 0.96 and 3.0% for the 1RM squat. Relative upper- and lower-body strength were calculated by dividing the 1RM of the bench press, chin-up and squat by the player's body mass [102].

Statistical analysis

Normal distribution of the data was examined using the Shapiro-Wilk test. Independent t-tests were used to determine if differences existed between the first grade and second grade players for muscular strength, power, and tackling ability. Differences in physiological variables and tackling abilities between the two different playing levels were also compared using Cohen's effect size (ES) statistic [79]. ES of <0.2, 0.2-0.6, 0.61-1.2, 1.21-2.0, and >2.0 were considered trivial, small, moderate, large, and very large, respectively [106]. Pearson product moment correlation coefficients were used to determine the relationships among muscular strength and power, and over-the-ball and under-the-ball tackling ability. Correlation coefficients of 0.1-0.3, 0.31-0.5, 0.51-0.7, >0.71 were considered small, moderate, large, and very large respectively [106]. The level of significance was set at $P < 0.05$.

8.4 Results

First grade players were significantly heavier than second grade players ($P = 0.01$, ES = 1.03, 95% CI 0.20-1.75). The 1RM chin-up for first grade players was significantly greater ($P = 0.004$, ES = 1.11, 95% CI 0.35-1.92) than the second grade players. First grade players also had greater CMJ ($P = 0.005$, ES = 1.19, 95% CI 0.43-2.03) and PPU ($P = 0.03$, ES = 0.80, 95% CI 0.26-1.82) peak power outputs than the second grade players (Table 8.1).

Table 8.1. Physiological qualities of semi-professional rugby league players.

	First Grade (n = 19)	Second Grade (n = 12)	Effect Size
Body Mass (kg)	100.2 ± 11.9*	88.5 ± 11.2	1.03 (0.20-1.75)
1RM Squat (kg)	156.7 ± 26.5	148.6 ± 23.2	0.33 (-0.43-1.05)
1RM Bench (kg)	131.3 ± 21.5	122.2 ± 18.4	0.47 (-0.31-1.18)
1RM Chin-up (kg)	129.9 ± 11.2**	116.0 ± 13.2	1.11 (0.35-1.92)
Relative Squat (kg·kg ⁻¹)	1.57 ± 0.25	1.68 ± 0.16	-0.57 (-1.23-0.28)
Relative Bench (kg·kg ⁻¹)	1.31 ± 0.17	1.39 ± 0.16	-0.45 (-1.21-0.28)
Chin-up (kg·kg ⁻¹)	1.31 ± 0.12	1.32 ± 0.10	-0.10 (-0.82-0.65)
CMJ Peak Power (W)	5500 ± 715**	4770 ± 555	1.19 (0.43-2.03)
PPU Peak Power (W)	1556 ± 421*	1192 ± 468	0.80 (0.26-1.82)
CMJ Peak Power (W·kg ⁻¹)	55.02 ± 5.19	54.13 ± 4.29	0.19 (-0.53-0.94)
PPU Peak Power (W·kg ⁻¹)	15.70 ± 4.66	13.51 ± 5.27	0.43 (-0.18-1.31)

RM = repetition maximum; CMJ = Countermovement jump; PPU = Plyometric push-up

Data are means ± SD. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large (95% confidence intervals).

* Significant at $P < 0.05$.

** Significant at $P < 0.01$.

The results of the standardised tackling tests for the first and second grade players are shown in Table 8.2. In the under-the-ball tackling ability test, first grade players had significantly greater scores ($P = 0.03$, ES = 0.84, 95% CI 0.07-1.50) and more regularly produced leg drive upon contact ($P = 0.03$, ES = 0.80, 95% CI 0.06-1.58) than the second grade players. Similarly, in the over-the-ball tackling ability test, first grade players had significantly greater scores ($P < 0.001$, ES = 1.86, 95% CI 0.83-2.52) than the second grade players. In the over-the-ball drill, first grade players more frequently watched the ball-carrier into contact ($P < 0.001$, ES = 1.62, 95% CI 0.90-2.61), made contact with the chest or shoulder ($P = 0.03$, ES = 0.73, 95% CI -0.03-1.49) and maintained a square and aligned body position ($P = 0.05$, ES = 0.85, 95% CI 0.09-1.63).

Table 8.2. Standardised tackling ability tests of first and second grade players.

	First Grade (n = 19)	Second Grade (n = 12)	Effect Size
Under-the-ball tackling ability (%)	78.7 ± 10.2*	69.8 ± 10.9	0.84 (0.07-1.50)
Contact centre of gravity (AU)	5.8 ± 0.4	5.8 ± 0.4	0.02 (-0.71-0.76)
Initial contact with shoulder (AU)	5.7 ± 1.0	5.5 ± 0.8	0.22 (-0.54-0.94)
Square and aligned (AU)	3.7 ± 1.5	2.8 ± 1.6	0.60 (-0.16-1.34)
Leg drive upon contact (AU)	4.4 ± 1.7*	2.9 ± 2.0	0.80 (0.06-1.58)
Watch target onto shoulder (AU)	3.1 ± 1.7	2.3 ± 1.7	0.48 (-0.28-1.21)
Centre of gravity over base of support (AU)	5.7 ± 1.0	5.8 ± 0.4	-0.23 (-0.92-0.56)
Over-the-ball tackling ability (%)	71.4 ± 10.1**	55.3 ± 7.9	1.86 (0.83-2.52)
Contact on ball (AU)	6.0 ± 0.0	5.8 ± 0.4	0.53 (0.05-1.47)
Contact with shoulder and chest (AU)	5.8 ± 0.4*	5.3 ± 0.9	0.73 (-0.01-1.50)
Square and aligned (AU)	3.4 ± 1.6*	2.3 ± 1.1	0.85 (0.09-1.63)
Leg drive upon contact (AU)	2.2 ± 2.1	2.4 ± 1.9	-0.13 (-0.86-0.61)
Watch target into contact (AU)	5.1 ± 1.3**	2.3 ± 1.9	1.62 (0.90-2.61)
Minimise space between head, hips and feet (AU)	3.4 ± 1.9	1.8 ± 2.1	0.73 (-0.03-1.49)

Individual variable represents a score from a possible score of 6 (i.e. the sum of 6 trials). AU = Arbitrary units

Data are means ± SD. Tackling ability score presented as a percentage. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large (95% confidence intervals).

* Significant at $P < 0.05$.

** Significant at $P < 0.01$.

Table 8.3 shows the relationship between physiological characteristics and tackling ability as measured by the under-the-ball and over-the-ball tackle tests. A large, significant relationship was found between the scores of the under-the-ball and over-the-ball tackling ability tests ($r = 0.55$, 95% CI 0.24-0.76, $P = 0.001$) (Figure 8.2). Under-the-ball tackling ability was moderately related to 1RM squat ($r = 0.37$, 95% CI 0.02-0.64, $P = 0.40$), while the over-the-ball tackling ability was moderately related to PPU peak power ($r = 0.39$, 95% CI 0.04-0.65, $P = 0.031$).

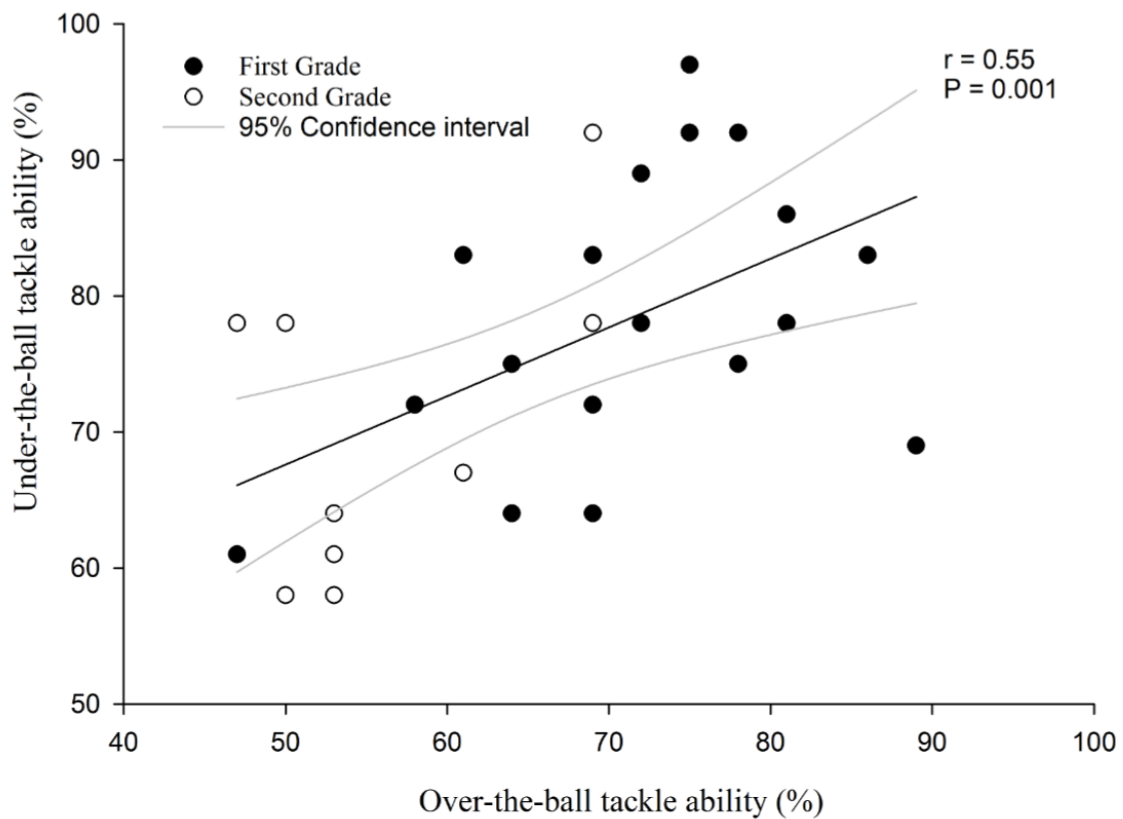


Figure 8.2. Over-the-ball vs under-the-ball tackle ability

Table 8.3. Relationship between tackling abilities and physiological characteristics.

	Under-the-ball tackle ability	Over-the-ball tackle ability
Body Mass (kg)	0.43*	0.29
	0.09-0.68	-0.07-0.58
1RM Squat (kg)	0.38*	0.01
	0.03-0.65	-0.35-0.36
1RM Bench (kg)	0.21	0.03
	-0.16-0.53	-0.33-0.38
1RM Chin-up (kg)	0.26	0.16
	-0.10-0.56	-0.21-0.49
Relative Squat (kg·kg ⁻¹)	0.05	-0.26
	-0.31-0.40	-0.56-0.10
Relative Bench (kg·kg ⁻¹)	-0.20	-0.26
	-0.52-0.17	-0.56-0.10
Chin-up (kg·kg ⁻¹)	-0.34	-0.23
	-0.62-0.02	-0.54-0.14
CMJ Peak Power (W)	0.33	0.18
	-0.03-0.61	-0.19-0.50
PPU Peak Power (W)	0.33	0.39*
	-0.03-0.61	0.04-0.65
CMJ Peak Power (W·kg ⁻¹)	-0.18	-0.17
	-0.50-0.19	-0.49-0.20
PPU Peak Power (W·kg ⁻¹)	0.16	0.30
	-0.21-0.49	-0.06-0.59

RM = repetition maximum; CMJ = Countermovement jump; PPU = Plyometric push-up
Data are reported as Pearson product moment correlation coefficients (95% confidence intervals).

* Significant at $P < 0.05$.

** Significant at $P < 0.01$.

8.5 Discussion

This is the first study to investigate tackling ability in rugby league players with an over-the-ball tackle ability drill. The results of this study showed that the first grade players had superior tackle ability in both the under-the-ball and over-the-ball tackling drills. Furthermore, it was found that absolute lower-body strength was associated with under-the-ball tackling ability, whereas over-the-ball tackling ability was related to peak power of the PPU.

The first grade squad demonstrated superior under-the-ball tackling ability when compared to the second grade team. In this study, first grade players more regularly presented leg drive upon contact than second grade players during the one-on-one standardised tackle drill. Leg drive has been a criteria for assessing rugby league one-on-one tackle ability in multiple studies [10, 16, 91]. This finding supports recent research which found that leg drive was significantly associated with tackle success in rugby union match-play [23]. The results of this current study are consistent with other studies which have shown that tackling ability is improved rugby league players as playing levels increases [14, 16, 85]. Furthermore, players exhibiting superior under-the-ball tackling ability have been shown to perform a greater proportion of dominant tackles and fewer missed tackles in match-play [10, 91]. The findings of this study provide further support for the practical utility of the under-the-ball tackling drill to assess tackling ability in rugby league players.

First grade players produced superior results in the over-the-ball tackling ability drill compared to second grade players. First grade players more regularly made contact with the shoulder or chest, maintained a square and aligned body position, and watched the

ball-carrier into contact. This finding validates the criteria used to evaluate over-the-ball tackling ability in an “off-field” setting. It is recommended that future research investigates the relationship between the over-the-ball tackling ability test and match-play tackling performance in rugby league players.

This study found that there was a large, significant relationship between the two different tackling drills. This finding is to be expected given the commonality in the technical criteria assessing the two tackling ability drills, namely maintaining leg drive upon contact, body position square and aligned, and watching the target into contact. It must be noted that on average both first grade and second grade players scored lower in the over-the-ball tackling test than the under-the-ball tackling test. Furthermore, there was a much larger difference between groups in the over-the-ball tackling ability test than the under-the-ball tackling ability test (16.1% vs. 8.9%). This finding suggests that the over-the-ball tackle is a more difficult skill to execute than the under-the-ball tackle. On average, both groups were less able to produce leg drive in the over-the-ball drill compared to the under-the-ball drill. This is most likely due to the different body positions of the tackles. The under-the-ball tackle is performed with the player’s centre of gravity forward to their base of support, with hips and knees in moderate flexion. This body position is a more advantageous position for producing leg drive than the upright body position required for the over-the-ball tackle. The ability to provide feedback to players through the analysis of the over-the-ball tackling drill based on the technical criteria used in this study may assist in the development of this skill.

Lower-body strength, as measured by the 1RM squat, was shown to be moderately associated with under-the-ball tackling ability. This finding is consistent with previous

research [85, 91, 101], and is consistent with the findings of others that has shown that improvements and decrements in lower-body strength were related to enhanced and decreased performance, respectively, in the under-the-ball tackling drill [92, 111]. Furthermore, it has been shown that players with greater relative lower-body strength had greater under-the-ball tackling ability under fatigued conditions [101]. Collectively, the findings of these studies suggest that lower-body strength is an important contributor to under-the-ball tackling ability.

Body mass was found to be moderately related to under-the-ball tackling ability. This finding is in agreement with previous research investigating the relationships between physical qualities and tackling ability in semi-professional rugby league players [85]. In rugby league, body mass has been shown to be a critical component in the production of momentum in collision events [11]. Interestingly, the over-the-ball tackle ability was not significantly related to over-the-ball tackle ability in this study. Future studies should examine the anthropometric and physical characteristics associated to over-the-ball tackle performance.

The plyometric push-up performance was moderately associated with over-the-ball tackling ability. This finding appears logical as the over-the-ball tackle requires the defender to smother the ball-carrier with the upper-body to effect the tackle. Lower-body strength was not significantly associated with the over-the-ball tackle. As previously stated, this is most likely a reflection of the different body position required to perform the two types of tackles. The (r^2) of the plyometric push-up was 15%, meaning that 85% of the variance in tackling ability was explained by factors in addition to, or other than PPU performance. While this study provides an important step in explaining the influence

of muscular strength and power on over-the-ball tackling ability, it must be acknowledged that additional factors (e.g. specific skill, experience) may explain a greater proportion of tackling ability. Given the prevalence of over-the-ball tackles in rugby league match-play, further research examining this specific skill is warranted [91].

8.6 Practical Applications

The over-the-ball tackling drill was not developed as a substitute for the under-the-ball tackle assessment but was designed to be used in conjunction with the under-the-ball tackling drill to provide more comprehensive feedback on the tackling abilities of players. Although correlated, this study showed considerable variance in the two tackling ability drills, suggesting that the over-the-ball and under-the-ball drill are two different skills and should be assessed and trained accordingly.

The findings of this study demonstrate that well-developed muscular strength and power contribute in some capacity to tackling ability in semi-professional rugby league players. Although a significant correlation does not suggest causation, it does provide valuable insight into the physiological variables that effect tackling ability. It can be assumed that as long as the technical aspects of tackling technique are adequately coached and practiced, than enhancements in muscular strength and power may serve as foundational components to underpin improvements in tackling ability. This is of particular importance to strength and conditioning specialists and rugby league coaches when evaluating and addressing deficiencies in players' tackling ability.

8.7 Conclusion

This study is the first to assess an alternate tackle ability drill for rugby league players. This study found that over-the-ball tackling ability was significantly associated with under-the-ball tackling ability in semi-professional rugby league players and that both tackle drills distinguished between higher- and lower-skilled players. Furthermore, it was found that peak power measured in the PPU was significantly related to over-the-ball tackling ability and absolute lower-body strength was associated with under-the-ball tackling ability.

**Chapter 9: Relationship between Two Standardised Tackling Proficiency Tests
and Rugby League Match-Play Tackle Performance**

Speranza, Michael J. A, Gabbett T. J, Greene, David A, Johnston, Rich D, Townshend, Andrew D. Relationship between Two Standardised Tackling Proficiency Tests and Rugby League Match-Play Tackle Performance. *International Journal of Sports Physiology and Performance*. 2018.

9.1 Abstract

This study investigated the relationship between two different assessments of tackling ability, physical qualities, and match-play performance in semi-professional rugby league players. Eighteen semi-professional rugby league players (mean \pm SD age, 23.1 ± 2.0 yrs; mass 98.8 ± 11.8 kg) underwent tests of upper- and lower-body strength and power. Tackling ability was assessed using video analysis under-the-ball and over-the-ball tackle drills. A total of 2,630 tackles were analysed from match-play. Over-the-ball tackle ability was positively related to the proportion of dominant tackles ($r_s = 0.52$, 95% CI 0.07 to 0.79, $P = 0.03$) and average play-the-ball speeds ($r_s = 0.50$, 95% CI 0.04 to 0.78, $P = 0.03$), and negatively related to tackles that conceded offloads ($r_s = -0.55$, 95% CI -0.78 to 0.04, $P = 0.04$). Under-the-ball tackle ability was significantly related to the proportion of dominant tackles ($r_s = 0.57$, 95% CI 0.14 to 0.82, $P = 0.01$) and missed tackles ($r_s = -0.48$, 95% CI -0.77 to 0.02, $P = 0.05$). Good over-the-ball tacklers performed proportionally more dominant tackles, allowed significantly fewer offloads, and had longer average play-the-ball speeds. Good under-the-ball tacklers missed proportionately fewer tackles. This study suggests that both the under-the-ball and over-the-ball standardised tackle assessments are associated with varying indicators of match-play tackle performance and justifies the practical utility of these tests to assess and develop both types of tackles.

9.2 Introduction

The tackle is one of the most crucial elements in the collision sports of rugby league and rugby union [5, 32]. Tackling proficiency, the ability to dominate the tackle contest, and the tolerance of physical impacts is fundamental to success in these sports [5]. It has been shown that winning teams allow fewer metres in defence and are involved in fewer ineffective tackles than losing teams [32, 100]. An increasing body of research has examined tackling ability in rugby league players through the video analysis of a standardised one-on-one tackling drill [10, 51, 91]. These studies investigated tackle ability through the assessment of the traditional shoulder tackle, also known as the under-the-ball tackle. The under-the-ball tackle is characterized by the defender making initial contact with their shoulder at the torso region of the ball-carrier.

A 2008 study investigating tackle characteristics in the Australian National Rugby League competition concluded that the majority of tackles were performed at the mid torso of the ball-carrier [21]. However, a more recent study (2015) investigating tackling ability in semi-professional rugby league match-play found that approximately 70% of tackles were executed around the ball-carriers chest and shoulders and fewer than 25% of tackles were made at the torso region [91]. Tackles made at the shoulder and chest region are commonly referred to as “over-the-ball” or “smother tackles”. Research investigating the relationships between match-play tackle characteristics and outcomes found that the likelihood of an offload is decreased when the initial contact zone was at the chest and shoulders compared to contact at the torso or legs [107]. Furthermore, it has been found that the smother tackle was as likely to have successful defensive outcomes in both rugby league and rugby union match-play compared to the traditional shoulder tackle [23, 107]. Due to the prevalence and the positive performance outcomes associated with an over-

the-ball tackle, from a coach's perspective, it will be useful to examine this type of tackle in a specific drill.

Gabbett and Ryan [10] examined tackle ability in professional players by analysing a standardised under-the-ball tackling drill, categorizing players as “good” or “poor” tacklers based on a median split. “Good” tacklers were involved in a greater proportion of dominant tackles and missed proportionately fewer tackles than ‘poor’ tacklers [10]. Similarly, semi-professional players with good under-the-ball tackling ability on a standardised proficiency test were involved in a greater proportion of dominant tackles and missed a smaller proportion of tackles during match-play [91]. These studies have highlighted the association between under-the-ball tackling ability and match-play performance. However, to date no study has investigated the relationship between an over-the-ball tackle ability drill and rugby league match-play tackle performance.

Lower- and upper-body strength, as well as upper-body power have been shown to be significantly related to under-the-ball tackling ability in semi-professional rugby league players [85, 101]. Furthermore, greater lower-body strength and lower-body power have been shown to be significantly associated with the proportion of dominant tackles made during match-play [15, 91]. Previous research has highlighted that muscular strength and power attributes influence tackle performance however, in these studies upper-body strength and power were only measured from pushing movements, namely the bench press and plyometric push up. Previous research has identified that upper-body pulling strength is greater in elite compared with sub-elite players [112]. Given the amount of grappling and wrestling that can occur during a tackle, where a player's posterior or pulling strength might be contributing to tackling ability.

Research examining tackling in rugby league has focused on the association between physical characteristics and under-the-ball tackling ability on tackle performance outcomes. To date, no research has examined how a standardised over-the-ball tackle ability assessment is related to game specific tackle measures. The primary purpose of this study was to investigate the relationships between two different assessments of tackling ability and match-play performance in semi-professional rugby league players. This study also examined the relationship between muscular strength and power, tackling abilities and match tackle performance.

9.3 Methods

Eighteen semi-professional rugby league players (mean \pm SD age, 23.1 ± 2.0 yrs; mass 98.8 ± 11.8 kg) participated in this study. Players were categorized into two positional groups, forwards (prop, second row, lock and hooker) ($n = 8$, 22.9 ± 2.0 yrs, 107.7 ± 11.0 kg) and backs (half-back, five-eighth, centre, winger and fullback) ($n = 10$, 23.4 ± 2.1 yrs, 91.7 ± 6.4 kg). All players were from one rugby league club competing in a state level competition, which is second tier to the national competition. Players were classified as semi-professional as they received remuneration for playing rugby league but also relied on other forms of income. Players were free from injury and mid-way through a fifteen week preseason training program when they undertook muscular strength and power testing, and a tackling assessment. All players received a detailed explanation of the study, including information on the risks and benefits, and written informed consent was obtained before the start of the study. All procedures were approved by the Australian Catholic University Ethics Committee (2013 01Q) prior to data collection.

The tests were conducted over the course of 2 training sessions. The tackling ability tests were conducted during at the start of the first training session. The power and strength data was collected at the second training session approximately 56 hours after the tackling ability tests. All players were familiar with the testing protocols as they were part of their routine training and testing. The players were instructed to be adequately hydrated prior to the sessions and to refrain from excessive exercise for 48 hours before the testing sessions.

Tackling ability was examined in two tests, an under-the-ball drill and an over-the-ball drill. Both drills were conducted in a 10 metre grid with video cameras (Sony AX100, Sony, Japan) positioned on the left, right and rear of the drills. The protocol for the tackle drills were the same as previous research examining tackle ability in rugby league players.[10, 16, 91] In both drills players performed six consecutive tackles, three on their right side and three on the left side, on another player of similar height and mass. The players were instructed to run directly at each other (the ball carrier was to make no evasive actions) so that the initial contact was made at approximately the five metre mark of the grid. During the under-the-ball tackle assessment the ball-carrier wore a diamond tackle shield (Madison Sport, Brisbane, Australia).The players were instructed to walk back to the start position after each tackle, allowing approximately 30 seconds between each tackle to minimise the effects of fatigue. A randomized-counterbalanced design was used, whereby nine players performed the under-the-ball tackle drill first and then performed the over-the-ball drill following a 30 minute passive break. The other nine players performed the two tackle drills in the reverse order.

The under-the-ball drill was assessed using the same criterion previously used to examine tackling ability through the video analysis of a standardised one-on-one defensive drill [13, 14, 16]. The technical criteria for assessing the over-the-ball drill was developed through collaboration of two expert rugby league coaches and were the same cues used during defensive drills at training. The criteria used for the assessment of the two drills are shown in Figure 9.1a and 9.1b.



Figure 9.1a. Under-the-ball tackle criteria

i) Contact made at the centre of gravity of the ball-carrier; ii) initial contact made with the shoulder; iii) body position square and aligned; iv) leg drive upon contact; v) watch the target onto the shoulder; vi) centre of gravity forward to the base of support



Figure 9.1b. Over-the-ball tackle criteria

i) Contact made on the ball; ii) initial contact made with the shoulder or chest; iii) body position square and aligned; iv) leg drive upon contact; v) watch the target into contact; vi) actively minimise space between the ball carrier's head, hips and feet

One analyst assessed the tackling ability of both drills using Dartfish video analysis software (Premium version for Windows, Dartfish, Switzerland). Each tackle received a score out of 6. Players were awarded 1 point for each criteria they achieved or 0 points if they failed to meet the criteria while performing a tackle. The players received an aggregate score (arbitrary units) from all 6 tackles in each drill, which was then converted to percentages. The intraclass correlation coefficient (ICC) for test-retest reliability and typical error of measurement (TEM) for the under-the-ball tackle assessment were 0.88 and 3.9%, and 0.93 and 1.5% for the over-the-ball tackle assessment, respectively.

Under the guidance of a strength and conditioning specialist, a one repetition maximum (1RM) bench press and chin up were used to assess upper-body strength and the back squat to test lower-body strength. For the back squat and bench press, players performed increasingly heavier loads using a standard 20 kg Olympic barbell, with a minimum of 3 minutes rest between sets, until they attempted a load that they could lift only once with appropriate form and technique. For the back squats, players were required to perform the movement to a below parallel thigh position (i.e. they descended to a position where the hip crease passed below the middle of the knee joint) and for the bench press it was essential for the bar to touch the chest before the ascending phase.

The same loading protocols were used for assessment of the 1RM weighted chin-up. The 1RM weighted chin-up was calculated by adding the body mass of the player to the additional mass added to the player via a belt. Players were required to perform a supinated grip chin-up starting with arms fully extended. An attempt was deemed successful if the player was able to pull their body upwards until their chin, with their head in a neutral position, was over the bar. The ICC was 0.98 and 2.8% for the 1RM

bench press, 0.98 and 2.7% for the 1RM chin-up and, 0.96 and 3.0% for the 1RM squat. Relative upper- and lower-body strength were calculated by dividing the 1RM of the bench press, chin up and squat by the player's body mass [102].

A countermovement jump (CMJ) and plyometric push-up (PPU) were performed on a force platform (Kistler 9290AD Force Platform, Kistler, Switzerland) to quantify lower- and upper-body peak power, respectively. The CMJ was performed with hands on hips and the PPU was performed from a standard push up position with arms fully extended. When instructed, the players descended to a self-selected depth before explosively jumping or pushing as high as possible off the platform. Players had two attempts with approximately 2 minutes recovery between each effort; their highest power output was used for analysis. The ICC and TEM for CMJ peak power were 0.81 and 3.5%, respectively, and for the plyometric push-up were 0.97 and 3.8%, respectively. To minimise the effect of fatigue, the strength and power tests were conducted 56 hours after any previous training sessions and players were instructed to refrain from strenuous exercise prior to the testing session.

Eighteen semi-professional rugby league matches played in the 2016 season were analysed from video recordings of the matches. A total of 2,360 tackle involvements were examined from the players who undertook the strength power tests and tackling ability assessments. The players competed in an average of 10 games (range: 3 to 17) and were involved in an average of 13 tackle events per match (range: 4 to 26). The outcome data on each of the player's involvement in a tackle contest were recorded. The data recorded on tackle outcomes were if the tackle was dominant or not, if the tackle was a missed tackle, if that tackle conceded an offload, if the tackle caused an error, and duration of the

play-the-ball. A tackle was deemed to be dominant if the time from when the ball-carrier's forward momentum had been halted to when the ball touched the foot during the play-the-ball exceeded four seconds or the tackle resulted in an offensive error. A missed tackle was defined as any unsuccessful attempt to complete a tackle where the tackler/defender had made contact with the ball-carrier and broke from the tackle before it was completed. An offload was coded when the ball-carrier was able to pass the ball to a teammate during the tackle. The play-the-ball duration was the time between the ball-carriers cessation of forward momentum and the moment the ball touched the foot during the play-the-ball.

The same analyst who assessed the standardised one-on-one tackling ability test also coded the tackle outcomes for all 18 matches. This ensured consistency with the interpretation and coding of the game-specific definitions. Although only one analyst was used, it is anticipated that when using a human observer that there is a level of subjectivity [99]. The intra-coder reliability was determined by randomly selecting one match and analysing a second time. Coding for the same match was separated by 21 days. Cohen's Kappa coefficient (κ) was used to evaluate the intra-reliability of the coder [105]. All variables had a kappa statistic of 0.92 or greater. A kappa statistic between 0.81 to 0.99 represents an "almost perfect" agreement between repeated measures [99, 105].

All data were analysed using SPSS (version 23 for Windows, SPSS Inc., USA). Due to the data not being normally distributed, non-parametric tests and magnitude based inferences were used. Spearman's rank order correlation coefficients were used to determine the relationships among muscular strength and power, tackling ability and match-play tackling characteristics and outcomes. Data were reported as Spearman's rank correlation coefficients (r_s) and 95% confidence intervals (CI). Players were divided into

“good tacklers” and “poor tacklers” for both tackling drills. This was based on a median split of the tackling ability results after controlling for playing position, with each group receiving an equal number of forward and backs.

Kruskal-Wallis test was used to establish statistical differences in muscular strength and power, tackling ability, and match-play tackling performance between good and poor tacklers. The level of significance was set at $P \leq 0.05$. Differences in physiological variables and tackling ability between the good and poor tacklers were also compared using Cohen’s effect size (ES) statistic.[79] Effect sizes of <0.2, 0.2-0.6, 0.61–1.2 1.21-2.0, and >2.0 were considered trivial, small, moderate, large, and very large, respectively [106].

9.4 Results

Table 9.1 shows the relationships between under-the-ball and over-the-ball tackle abilities and match-play tackle performance. A significant association ($r_s = 0.48$, 95% CI 0.02 to 0.77, $P = 0.05$) was found between under-the-ball and over-the-ball tackle abilities. Over-the-ball tackle ability was positively associated with the proportion of dominant tackles ($r_s = 0.52$, 95% CI 0.07 to 0.79, $P = 0.03$) and average play-the-ball speeds ($r_s = 0.50$, 95% CI 0.04 to 0.78, $P = 0.03$). Furthermore, over-the-ball tackle ability was negatively related to the proportion of tackles that conceded an offload ($r_s = -0.55$, 95% CI -0.78 to 0.04, $P = 0.04$). Under-the-ball tackle ability was also significantly related to the proportion of dominant tackles ($r_s = 0.57$, 95% CI 0.14 to 0.82, $P = 0.01$) and negatively related to the proportion of missed tackles ($r_s = -0.48$, 95% CI -0.77 to 0.02, $P = 0.05$).

Table 9.1. Relationships between tackle ability and match-play tackle outcomes

	OTB TA	UTB TA	Missed	Offloads	Dominant	Errors	PTB
OTB TA	1.00						
UTB TA	0.48* (0.02-0.77)	1.00					
Missed	-0.11 (-0.55 to 0.38)	-0.48* -0.77 to -0.02)	1.00				
Offloads	-0.50* (-0.78 to -0.04)	-0.32 -0.68 to 0.17)	0.27 (-0.23 to 0.65)	1.00			
Dominant	0.52* (0.07 to 0.79)	0.57* (0.14 to 0.82)	-0.16 (-0.58 to 0.33)	-0.61** (-0.84 to -0.20)	1.00		
Errors	0.38 (-0.11 to 0.72)	0.07 (-0.41 to 0.52)	0.04 (-0.43 to 0.50)	-0.20 (-0.61 to 0.29)	-0.09 (-0.53 to 0.39)	1.00	
PTB	0.50* (0.04 to 0.78)	0.23 (-0.27 to 0.63)	0.00 (-0.47 to 0.47)	-0.45 (-0.76 to 0.02)	0.74** (0.42 to 0.90)	0.02 (-0.45 to 0.48)	1.00

Abbreviations: OTB TA, Over-the-ball tackle ability; UTB TA, Under-the-ball tackle ability; Missed, proportion of missed tackles; Offloads Conceded, proportion of off-loads conceded per game; Dominant, proportion of dominant tackles; Errors, the proportion of errors forced each game; PTB, average play-the-ball speed (s).

Note: Data are reported as Spearman's rank order correlation coefficients, r_s and 95% confidence interval (in parentheses).

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

Table 9.2 shows the relationships between tackle abilities and muscular strength and power qualities. Under-the-ball tackle ability was significantly related to 1RM squat ($r_s = 0.55$, 95% CI 0.11 to 0.81, $P = 0.02$). Over-the-ball tackle ability was significantly related to 1RM chin up ($r_s = 0.56$, 95% CI 0.13 to 0.81, $P = 0.02$). No muscular strength and power qualities were related to match-play tackle performance.

Table 9.2. Relationships between tackle ability and muscular strength and power

	Over-the-ball TA	Under-the-ball TA
Body Mass	0.03 (-0.44 to 0.49)	0.45 (-0.02 to 0.76)
1RM Squat	0.15 (-0.34 to 0.58)	0.55* (0.11 to 0.81)
1RM Bench Press	-0.07 (-0.52 to 0.41)	0.35 (-0.14 to 0.70)
1RM Chin up	0.56* (0.13 to 0.81)	0.43 (-0.05 to 0.75)
Relative Squat	0.17 (-0.32 to 0.59)	0.14 (-0.35 to 0.70)
Relative Bench Press	-0.15 (-0.58 to 0.34)	-0.05 (-0.51 to 0.43)
Relative Chin up	0.19 (-0.30 to 0.60)	-0.16 (-0.58 to 0.33)
CMJ	-0.16 (-0.58 to 0.33)	0.36 (-0.13 to 0.71)
PPU	0.05 (-0.43 to 0.51)	0.09 (-0.39 to 0.53)

Abbreviations: 1RM, 1-repetition maximum; Relative squat, squat relative to body mass; Relative bench, bench press relative to body mass; Relative chin up, chin up relative to body mass; CMJ, countermovement jump peak power; PPU, plyometric push-up peak power.

Note: Data are reported as Spearman's rank order correlation coefficients, r_s and 95% confidence interval (in parentheses).

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

The results of the standardised tackling tests for the first and second grade players are shown in Table 9.3 and Figure 9.2. In the under-the-ball tackling ability test, "Good" tacklers more regularly produced leg drive upon contact ($P = 0.01$, ES = 1.04, 95% CI 0.28-2.31) than the "Poor" tacklers. Similarly, in the over-the-ball tackling ability test, In the over-the-ball drill, first grade players more frequently made contact with the chest or shoulder ($P = 0.01$, ES = 1.06, 95% CI 0.39-2.46) and maintained a square and aligned body position ($P = 0.03$, ES = 1.26, 95% CI 0.18-2.19).

Table 9.3. Standardised tackling ability tests of “Good” and “Poor” players.

	Good Tacklers (n = 9)	Poor Tacklers (n = 9)	Effect Size
Under-the-ball tackling ability (%)	85.1 ± 6.8**	69.0 ± 8.1	2.11 (1.01-3.34)
Contact centre of gravity (AU)	5.9 ± 0.3	5.9 ± 0.3	0.00 (-0.93-0.92)
Initial contact with shoulder (AU)	5.9 ± 0.3	5.4 ± 1.3	0.34 (-0.49-1.38)
Square and aligned (AU)	4.2 ± 1.5	2.8 ± 1.3	1.11 (0.01-1.96)
Leg drive upon contact (AU)	5.2 ± 0.8*	3.11 ± 2.0	1.04 (0.28-2.31)
Watch target onto shoulder (AU)	3.6 ± 1.6	2.1 ± 1.8	0.82 (-0.14-1.78)
Centre of gravity over base of support (AU)	5.9 ± 0.3	5.6 ± 1.3	0.25 (-0.61-1.25)
Over-the-ball tackling ability (%)	78.8 ± 6.0**	62.1 ± 8.1	2.06 (1.05-3.41)
Contact on ball (AU)	6.0 ± 0.0	6.0 ± 0.0	-
Contact with shoulder and chest (AU)	6.0 ± 0.0*	5.4 ± 0.5	1.06 (0.39-2.46)
Square and aligned (AU)	4.1 ± 1.5*	2.3 ± 1.4	1.26 (0.18-2.19)
Leg drive upon contact (AU)	2.7 ± 2.6	1.8 ± 1.6	0.54 (-0.53-1.34)
Watch target into contact (AU)	5.4 ± 1.1	4.3 ± 1.9	0.57 (-0.28-1.62)
Minimise space between head, hips and feet (AU)	4.1 ± 1.6	2.6 ± 2.1	0.75 (-0.17-1.75)

Individual variable represents a score from a possible score of 6 (i.e. the sum of 6 trials). AU = Arbitrary units

Data are means ± SD. Tackling ability score presented as a percentage. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61-1.2 = moderate; 1.21-2.0 = large; >2.0 = very large (95% confidence intervals).

* Significant at $P < 0.05$.

** Significant at $P < 0.01$.

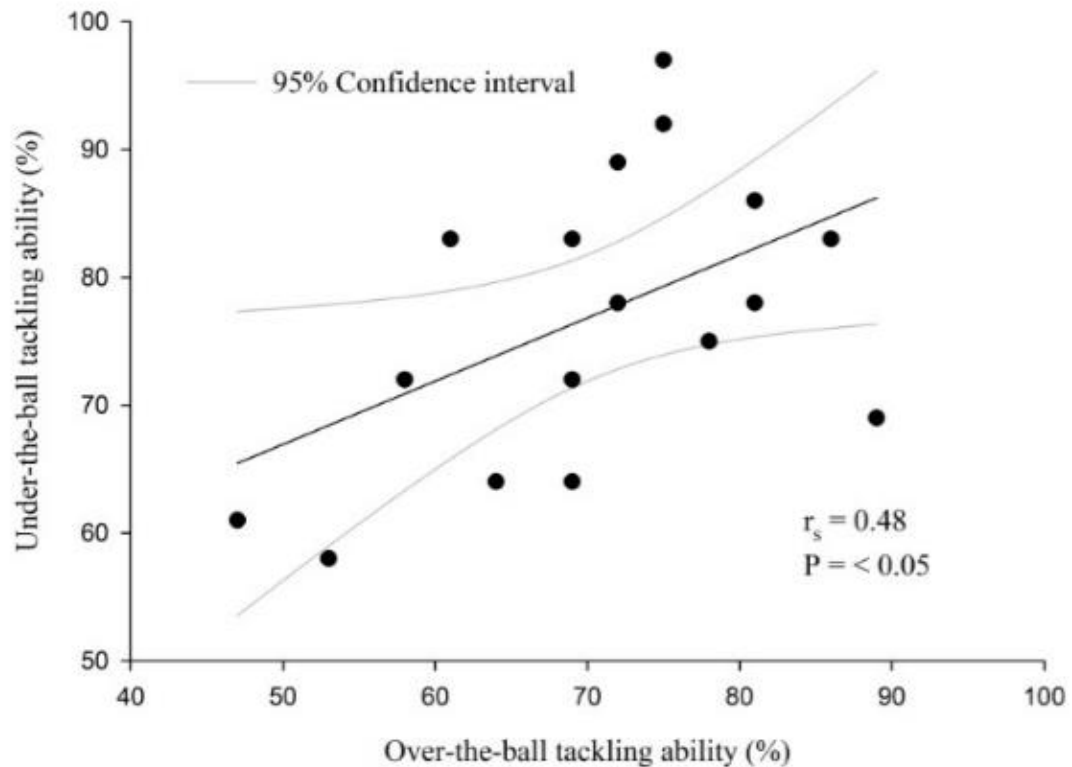


Figure 9.2. Under-the-ball vs over-the-ball tackling ability

Good under-the-ball tacklers were involved in a significantly smaller proportion of missed tackles ($P=0.04$; $ES=-0.98$) compared to the poor under-the-ball tacklers. Good over-the-ball tacklers performed proportionally more dominant tackles ($P = 0.01$; $ES = 1.32$), conceded significantly fewer offloads ($P = 0.02$; $ES = -1.29$), and had slower average play-the-ball speeds ($P = 0.03$; $ES = 1.05$) than the poor over-the-ball tacklers. Comparisons of match-play tackle performance between good and poor tacklers of the over-the-ball and under-the-ball tackle drills are shown in Table 9.4 and 9.5, respectively.

Table 9.4. Match-play tackling performance of “good” and “poor” over-the-ball tacklers

	Good (n=9)	Poor (n=9)	Effect Size	Difference
Over-the-ball TA (%)	78.8 ± 6.0**	62.1 ± 8.1	2.38 (1.1 to 3.4)	Very large
Tackles (n)	14.0 ± 6.4	12.1 ± 7.0	0.29 (-0.6 to 1.2)	Small
Missed Tackles (%)	10.1 ± 5.6	11.8 ± 4.7	-0.31 (-1.2 to 0.6)	Small
Offloads Conceded (%)	3.5 ± 1.8*	5.4 ± 1.2	-1.29 (-2.2 to -0.2)	Large
Dominant Tackles (%)	64.5 ± 12.0**	52.0 ± 5.9	1.32 (0.3 to 2.3)	Large
Forced Errors (%)	5.2 ± 5.0	2.4 ± 2.5	0.70 (-0.3 to 1.6)	Moderate
PTB (sec)	4.25 ± 0.17*	4.04 ± 0.23	1.05 (0.1 to 2.0)	Moderate

Note: Data are means ± SD. TA = tackling ability; PTB = play-the-ball. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

Note: 95% confidence interval (in parentheses).

* Significant at p<0.05.

** Significant at p<0.01.

Table 9.5. Match-play tackling performance of “good” and “poor” under-the-ball tacklers

	Good (n=9)	Poor (n=9)	Effect Size	Difference
Under-the-ball TA (%)	85.1 ± 6.8**	69.0 ± 8.1	2.15 (1.0 to 3.3)	Very Large
Tackles per game	11.2 ± 4.5	14.9 ± 8.0	-0.58 (-1.5 to 0.4)	Small
Missed Tackles (%)	8.7 ± 5.5*	13.2 ± 3.6	-0.98 (-1.9 to 0.1)	Moderate
Offloads Conceded (%)	3.8 ± 1.8	5.1 ± 1.6	-0.76 (-1.7 to 0.2)	Moderate
Dominant Tackles (%)	62.4 ± 11.7	54.1 ± 9.7	0.77 (-0.2 to 1.7)	Moderate
Forced Errors (%)	3.7 ± 4.5	3.9 ± 3.9	-0.04 (-0.6 to 1.3)	Trivial
PTB (sec)	4.19 ± 0.11	4.11 ± 0.29	0.34 (-0.6 to 1.3)	Small

Note: Data are means ± SD. TA = tackling ability; PTB = play-the-ball. Effect size, <0.2 = trivial; 0.2-0.6 = small; 0.61–1.2 = moderate; 1.21–2.0 = large; >2.0 = very large.

Note: 95% confidence interval (in parentheses).

* Significant at p<0.05.

** Significant at p<0.01.

9.5 Discussion

This was the first study to investigate the relationships between over-the-ball tackle ability and tackle performance of players during rugby league match-play. Similar to the findings of the under-the-ball tackle assessment, over-the-ball tackle ability was significantly related to the proportion of dominant tackles (positive) performed in match-play. However, unlike under-the-ball tackle ability, over-the-ball tackle ability was negatively related to the proportion of tackles performed that conceded an offload. This finding is consistent with previous rugby league match-play research that found when contact was initiated at the chest and shoulder region the odds of an offload occurring was much lower than if contact was made at the torso or legs [107]. In the present study, over-the-ball tackle ability was also related to greater average play-the-ball speed. The play-the-ball speed is considered a critical element in rugby league defense [100]. Slow play-the-balls provide an advantage to the defensive team, as it allows more time for defenders to recover and prepare for the next attacking play.

Consistent with previous research, results showed that under-the-ball tackle ability was significantly related to the proportion of dominant and missed tackles players made in match-play [10]. Furthermore, this finding is in partial agreement with earlier research in semi-professional rugby league players which found that tackle ability was significantly associated with dominant tackles in match-play [91]. However, the aforementioned study did not find that the proportion of missed tackles in match-play was statistically related to under-the-ball tackle ability [91]. The findings from the current study, along with previous research, confirm the practical utility of the under-the-ball tackle assessment.

Lower body strength, as measured by the 1RM squat, was significantly related to under-the-ball tackle ability. This finding is in partial agreement with previous research that found maximal squat and bench press, squat relative to body mass and upper-body pushing power were all significantly related to under-the-ball tackle ability [85]. Maximal chin up strength was the only muscular strength and power quality that was related to over-the-ball tackle ability. This finding most likely reflects the requirement of defenders to wrap their arms around the ball-carrier to affect the tackle and prevent an offload from occurring. It could be assumed that superior pulling strength would be beneficial when attempting to perform an over-the-ball tackle.

No muscular strength or power qualities were found to be significantly related to match-play tackle performance in this study. In contrast, previous research found that maximal lower-body strength, as measured by a 1RM squat, was significantly associated with the proportion of dominant tackles made during rugby league match-play [91]. The conflicting findings from the two studies might be explained by dissimilar team tactics, playing styles and/or individual playing abilities. Research investigating the relationships between tackle characteristics and tackle outcomes in semi-professional rugby league players found that no specific tackle characteristics (i.e. tackle type, contact zone, etc.) were associated with a dominant tackle outcome [107]. Collectively, the findings from the current study and previous research indicate that the ability and mechanism for players to dominate tackles may vary, possibly influenced by an individual's physical qualities, playing position or playing ability.

Consistent with previous research, “good” under-the-ball tacklers were involved in a smaller proportion of missed tackles during match-play compared to “poor” under-the-

ball tacklers [10, 91, 107]. Furthermore, although not statistically significant “good” under-the-ball tacklers performed moderately more dominant tackles and conceded fewer offloads than the “poor” tacklers. This finding is in agreement with previous research examining the relationships between match-play tackle performance and under-the-ball tackle ability [10, 91, 107]. When tackling ability was assessed from the over-the-ball tackling test, “good” tacklers performed significantly more dominant tackles, allowed significantly fewer offloads and had a significantly greater average play-the-ball speed than the “poor” over-the-ball tackling group. Unlike the under-the-ball tackle assessment, there was only a small, statistically non-significant difference in the proportion of missed tackles in the “good” and “poor” playing groups. The findings from this study indicate that proficiency in the two different tackle ability assessments are related to different match-play tackle outcomes.

The under-the-ball and over-the-ball tackling abilities were found to be moderately correlated. This finding is to be expected given the commonality in the technical criteria assessing the two tackling ability drills, namely maintaining leg drive upon contact, body position square and aligned, and watching the target into contact. Although correlated, figure 2 clearly demonstrates that proficiency in one of the drills does not necessarily translate to proficiency in the other. Furthermore, this study showed that the two tackle ability tests were related to different match-play tackle outcomes. Collectively, the results of this study indicate that the over-the-ball and under-the-ball tackle ability are two different skills and should be assessed, coached and developed accordingly.

9.6 Practical Applications

Our findings suggest that both the under-the-ball and over-the-ball standardised tackle assessment tests are related to match-play tackle performance indicators, thus justifying the practical utility of these off-field tests to assess tackling ability. Although correlated, this study showed that the two tackle ability tests were related to different match-play tackle outcomes, indicating that over-the-ball and under-the-ball tackle ability are two different skills and should be assessed and trained accordingly. From the perspective of a rugby league coach, the results from these standardised tackle assessments can assist in identification of strengths and weaknesses in the tackle technique of individual players. Furthermore, the data from these tests may assist coaches to formulate defensive strategies specific to the abilities of their players.

For the strength and conditioning specialist the findings of this study demonstrate that well-developed muscular strength and power contribute to tackling ability in rugby league players. While a significant correlation does not suggest causation, the results from this research provide insight into the physical characteristics that influence tackling ability. As long as the technical aspects of tackling technique are adequately coached and practiced, it can be assumed that the development of muscular strength and power may serve as foundational components to underpin improvements in tackling ability.

9.7 Conclusions

This is the first study to examine the relationships between over-the-ball and under-the-ball tackling abilities and match-play tackle performance. The findings of this study suggest that proficiency in the over-the-ball or under-the-ball tackling drill is related to different on-field tackle outcomes. Over-the-ball tackle ability was strongly related to the

proportion of dominant tackles, average play-the-ball speed and offloads conceded, while under-the-ball tackle ability was associated with fewer missed tackles in match-play. While match-play tackling requires accurate decision-making and sound defensive structures, this study has found that the under-the-ball and over-the-ball standardised 1-on-1 tackle drills are reliable and valid methods of evaluating tackling ability in rugby league players.

Chapter 10: Discussion, limitations and future research

This body of research investigated tackling ability in semi-professional rugby league players, from the perspective of a strength and conditioning coach. This was achieved by firstly, examining possible relationships between under-the-ball tackling ability and muscular strength and power in rugby league players. Secondly, the research explored tackle characteristics and outcomes during rugby league match-play and their relationship with tackle ability and physical qualities. The final studies of the thesis examined an alternate tackle assessment, the over-the-ball tackling drill, exploring its relationships with match performance and muscular strength and power characteristics. The following section highlights and discusses the main findings from the three main objectives.

10.1 Summary of Major Findings

10.1.1 Muscular strength and power and under-the-ball tackling ability

Throughout the research conducted in this thesis it was concluded that muscular strength and power is significantly related to under-the-ball tackling ability (as measured by the standardised under-the-ball tackle assessment), as well as match-play tackle performance.

The key findings were:

1. Under-the-ball tackle ability positively correlated to numerous strength and power characteristics; maximal back squat and bench press, back squat and bench press relative to body mass, and the peak power of the plyometric push up.
2. Improvements in lower-body strength, both maximal and relative to body mass, were significantly related to improvements in the under-the-ball tackle assessment.

3. Decrements in lower-body strength were related to declines in under-the-ball tackle assessment performance during a competitive season.
4. Absolute lower-body strength was positively related to the proportion of dominant tackles during match-play. Lower-body strength of the defender was also related to the ball-carrier being put on their back during the tackle contest.

This body of research is the first to investigate the relationships between muscular strength qualities and tackle ability in rugby league. In chapter 3 it was found that numerous strength and power characteristics, both upper- and lower body measures, were related to performance in the under-the-ball tackle assessment. However, the subsequent 6 experimental studies did not find any upper body strength and power qualities to be related to the under-the-ball assessment. The consistent finding throughout all the studies presented in this thesis was that lower-body strength, as measured by the back squat, was significantly related to under-the-ball tackling ability.

Previous research had concluded that lower-body power was significantly related to tackling ability in rugby league players, leading the authors to suggest that improvements in lower-body power may transfer to improvements in tackling ability [13, 14, 16]. In chapter 4, it was found that improvements in lower-body strength, both relative and absolute, and to a smaller extent lower-body power, following an 8-week strength training phase was significantly related to improvements in under-the-ball tackling ability. Although shown to be correlated to under-the-ball tackle ability in chapter 3, improvements in upper-body strength or power were not related to improvements in tackling ability. In chapter 5, it was found that players who maintained absolute and relative lower-body strength during a competitive season experienced a greater

improvement in tackling ability, than players who experienced decrements in 1RM squat and squat relative to body mass. Collectively, these results suggest that changes in lower-body strength influence under-the-ball tackling ability as measured by a standardised one-on-one tackling drill in semi-professional rugby league players.

These findings do not imply that the development of lower body strength is the most important contributor to the improvement in under-the-ball tackling ability. It must be acknowledged that a large variance in improvement or decrement in under-the-ball tackling ability is explained by factors other than changes in muscular strength and power characteristics. While the results from the collection of studies in this thesis provide an important step in explaining the influence of muscular strength and power on tackling ability, it must be acknowledged that aspects such as technical factors, experience, and match-exposure may explain a greater proportion of this skill. Therefore, if the technical aspects of tackling technique are adequately coached and practiced, then enhancements in lower-body strength may be one of the foundational components to underpin improvement in tackling ability.

While it has been shown that lower-body strength is positively related to under-the-ball tackling ability, the mechanisms for these changes remains speculative. It is possible that improvements in lower-body strength and power may enhance a players' ability to exert force in a tackle allowing them to improve leg drive through the tackle. This theory is supported by the findings in chapter 5, that players who maintained lower-body strength during a competitive season improved the regularity of leg drive upon contact during the standardised one-on-one drill. In comparison, players who experienced a decrement in lower-body strength showed a reduction in this technical criterion.

Improvements in change of direction speed and acceleration may offer another possible explanation for the improvement in tackling ability. Gabbett [13] reported that players with superior tackling ability had greater acceleration and change of direction speed and suggested that change of direction speed may affect how well players position themselves prior to making contact. Studies have found that increased lower-body strength and power is associated with improved acceleration and change of direction speed [86-88]. Sprint speed and change of direction were not examined in this thesis therefore this notion remains speculative.

From a match-play perspective, absolute lower-body strength of the tackler was found to be positively related to the proportion of dominant tackles made, as well as the ball-carrier being put on their back during the tackle contest. Interestingly, no pre-contact or contact tackle characteristics were associated with the dominant tackle outcome, which suggests that actions after the initial contact, such as wrestling, may be more influential in achieving dominant tackle outcomes. Collectively, these results suggest that high levels of muscular strength are advantageous for controlling the tackle contest to achieve a positive outcome for the tackler and highlight the importance of developing lower-body muscular strength in semi-professional rugby league players.

10.1.2 Match-play tackle characteristics, tackle performance and under-the-ball tackling ability

Chapters 6 and 7 examined relationships between the under-the-ball tackle assessment, match-play tackle characteristics and outcomes. The key findings from these two studies were:

1. The validation of the standardised one-on-one under-the-ball tackle assessment to evaluate tackle ability in semi-professional rugby league players.
2. Numerous tackle characteristics from both the ball-carrier and the defender related to an increased likelihood of missed tackles and offloads. No tackle characteristics were found to be related the chances of a dominant tackle.
3. No difference in tackle characteristics between “good” and “poor” tackling groups.

Gabbett and Ryan [10] highlighted the practical usefulness and validity of the under-the-ball tackle assessment in professional rugby league players. It was found the assessment of tackling ability discriminated players of different playing levels, finding players competing in the national competition had superior tackling ability compared to players in the second-tier competition. Furthermore, it was found that tackling ability was significantly related to the proportion of missed tackles (negative), as well as the proportion of dominant tackles (positive) made per game in professional rugby league [10]. In chapter 6 it was found that tackle ability, as assessed by the under-the-ball tackle drill, was significantly related (positive) to the proportion of dominant tackles that players made. In contrast, the subsequent experimental chapter concluded that the proportion of missed tackles was statistically associated (negatively) with tackle ability. A possible explanation for the difference in these findings is that only the first tackler in the tackle was examined in chapter 7, whereas all tackle involvements were coded in the chapter 6 study.

Throughout this body of research players were categorised as “good” or “poor” tacklers based on a median split of tackle ability while controlling for playing position. In chapter

6 and 7 it was found that “good” tacklers performed proportionally more dominant tackles, and conceded proportionally fewer missed tackles and tackles that allowed an offload. Based on the collective findings of these two studies, it can be concluded that the standardised one-on-one under-the-ball tackle drill is a valid assessment in semi-professional rugby league players, with this off-field tackling assessment providing information which is predictive of tackling performance in match-play.

Chapter 7 examined how tackle characteristics were related to match-play tackle outcomes and performance. This study found that the type of tackle and leg drive were significant predictors of successful tackle outcomes. These findings are in agreement with similar research examining rugby union match-play tackle characteristics [23]. Smother and shoulder tackle types had a decreased probability of a missed tackle when compared to arm or jersey tackles. Furthermore, the lack of leg drive by the defender upon contact increased the odds of a missed tackle by over 2.5 times. The body position of the defender was also a significant predictor of missed tackles, with defenders presenting a medium body position significantly decreasing the odds of a missed tackle compared to a high or low body position. These results further support the technical criteria used to assess under-the-ball tackling ability; specifically contacting the target with the shoulder, leg drive upon contact and centre of gravity over the base of support [14, 16, 85, 91].

Contact zone was not a significant predictor of missed tackles but predicted the capacity to prevent an offload. When the tackle contact was initiated in the chest and shoulder region, the opportunity of an offload greatly diminished. These findings are consistent with Hendricks et al [23] who found that low contact increased the probability of an offload. Furthermore, the likelihood of an offload was greatly reduced when contact was

made front-on rather than side-on, oblique or from behind. These results were expected, as contact made in the chest and shoulder region and front-on would suggest that the defender has made an attempt to impede the ball-carrier's ability to pass the football.

An interesting finding from these studies were that the type of tackle, contact zone, or the presence of leg drive were not related to a dominant tackle occurring. The ball-carrier being put on their side or back were the only characteristics that were related to dominant tackles. It is inherently more difficult and takes longer for the ball-carrier to get to their feet to play-the-ball from these positions thus explaining this finding. Lower- and upper body strength were significantly related to the ball-carrier being placed on their back and side. The results of this study suggest that factors after the initial contact, such as wrestling or number of players involved may be more influential in achieving dominant tackle outcomes.

In chapters 6 and 7 it was established that the “good tackling” group performed proportionally more dominant tackles, and conceded proportionally fewer missed tackles and tackles that allowed an offload than the “poor tackling” group. However, there was no significant difference in tackle characteristics between the two groups. A possible explanation for this finding is that match-play tackle characteristics may be influenced by position specific situations. The “good” and “poor” tackling groups were controlled for playing position, with each group containing an equal number of forwards and backs. Previous research examining tackling in rugby league match-play found that backs were more likely to be involved in one-on-one tackle contests, and were more likely to sprint greater than 10 metres into their tackles [22]. Although, “good” tacklers make

proportionally fewer unsuccessful tackles, a difference in tackle characteristics to achieve positive tackle outcomes may vary based on playing position.

10.1.3 Comparison between under- and over-the-ball tackling abilities

The final two experimental chapters are the first to investigate an alternate standardised one-on-one tackle assessment in rugby league, the over-the-ball tackle drill. Chapter 8 compared the two different tackle drills, while chapter 9 examined how the over-the-ball tackle drill related to match-play tackle performance. The key findings were:

1. The validation of the over-the-ball tackle assessment to evaluate tackle ability in semi-professional rugby league players.
2. Upper-body strength and power measures positively correlated to over-the-ball tackling ability.
3. The two tackling assessments related to different match-play tackle performance.

It was found that first grade players displayed superior over-the-ball tackling ability compared to second grade players. First grade players more regularly made contact with the shoulder or chest, maintained a square and aligned body position, and watched the ball-carrier into contact. Similarly, first grades more regularly performed leg drive on contact and maintained a square and aligned body position in the under-the-ball tackle assessment. The over- and under-the-tackle assessments were found to discriminate between playing levels in semi-professional rugby league players. The findings are also consistent with previous research which found that players competing in the NRL outperformed state level players in the under-the-ball tackle assessment [10]. The

combined results of these studies suggest that tackling ability improves as the competitive standard increases.

In chapter 9 it was found that over-the-ball tackle ability was positively related to the proportion of dominant tackles and negatively related to the proportion of tackles that conceded an offload. Furthermore, over-the-ball tackle ability was significantly related to slower play-the-ball speeds. Potentially, when successfully performed, the over-the-ball tackle allows the tackler to control the ball as it is being held between the ball carrier and the defender, making it more difficult for the attacker to play the ball. The play-the-ball speed is a critical element in rugby league defence as slow play-the-balls provide an advantage to the defensive team, as it allows more time for defenders to recover and prepare for the next attacking play [100].

Collectively, the findings from chapters 8 and 9 validate the criteria used to evaluate over-the-ball tackling ability. The over-the-ball assessment is related to match-play tackle performance indicators and discriminates between playing levels, thus suggesting that it is both valid and reliable. The findings from the final two experimental chapters of this thesis justify the practical utility of this off-field test.

Muscular strength and power correlates of the over-the ball tackle assessment were investigated in chapters 8 and 9. Interestingly these studies had conflicting findings. In the first of the two studies, peak power of the plyometric push up was found to be related to over-the-ball tackling ability, whereas in the second study maximal chin up strength was found to be associated with over-the-ball tackle ability. These findings most likely

reflect the increased requirement of defenders to use their upper-body to hold and manipulate the ball-carrier to affect the tackle.

The under-the-ball and over-the-ball tackling abilities were found to be moderately correlated. This finding was expected given the commonality in the technical criteria assessing the two tackling ability drills, namely maintaining leg drive upon contact, body position square and aligned, and watching the target into contact. Although correlated, the results presented in this research showed considerable variance in the two tackling ability drills, suggesting that proficiency in one assessment did not automatically translate to proficiency in the other.

In chapter 9 it was found that the two tackle ability tests were related to different match-play tackle outcomes. Both the under- and over-the-ball tackle assessments were related to the proportion of dominant tackles. However, the under-the-ball tackle assessment was related (negatively) to the proportion of missed tackles during match-play while the over-the-ball tackle ability was not. Conversely, the over-the-ball tackle assessment was negatively associated with the proportion of tackles that conceded an offload, as well as positively correlated to slower play-the-ball speed, while these relationships were not replicated with under-the-ball tackle ability. These findings indicate that over-the-ball and under-the-ball tackle ability are two different skills and should be assessed and trained accordingly.

10.2 Practical Applications

The common finding throughout this body of research is that muscular strength and power, in particular lower-body strength, is significantly related to tackle ability, changes

in under-the-ball tackling ability, as well as match-play tackle performance in semi-professional rugby league players. This is of particular importance to strength and conditioning specialists and rugby league coaches when evaluating and addressing deficiencies in player's tackling ability. The combined results from the studies presented in this thesis highlights the importance of the development and maintenance of lower-body muscular strength for effective tackling performance throughout the rugby league season. It must be acknowledged that a significant correlation does not suggest causation, but it does provide insight into the physiological variables that influence tackling ability. Provided the technical aspects of tackling technique are adequately developed and trained, then enhancements in strength and power, particularly lower body strength, may serve as foundational components to support the development of tackling ability.

Both the under-the-ball and over-the-ball tackle ability assessments have been shown to discriminate between playing levels and related to match-play tackle performance in semi-professional players. Although tackling during a rugby league match involves team defensive structures and a decision-making component, the combined findings of this research has demonstrated that both the under- and over-the-ball standardised one-on-one tackle drills to be reliable and valid methods to evaluate and monitor tackling ability.

It was shown in chapter 7 that key tackle characteristics were related to match-play tackle performance. It was concluded that presenting a medium body position, employing a smother or shoulder tackle, and producing leg drive upon contact are associated with successful tackle outcomes. It was also shown that front-on tackles, with a contact zone at the chest region decreased the odds of the ball-carrier offloading the football. These findings have significant implications for rugby league coaches in their approach to

developing tackling proficiency. It is recommended that coaches emphasise the fore-mentioned tackle characteristics in training drills to improve tackle ability and inform players on how certain tackle characteristics affect specific tackle outcomes.

In the last two experimental chapters, it was shown that under-the-ball and over-the-ball tackling abilities were found to be moderately correlated. Although correlated, it was highlighted in chapter 9 that proficiency in one of the drills does not necessarily translate to proficiency in the other. Furthermore, it was shown that the two tackle ability tests were associated with different match-play tackle outcomes. Collectively, these results indicate that the over-the-ball and under-the-ball tackle ability are two different skills and should be assessed, coached and developed accordingly. From the perspective of a rugby league coach, the results from these standardised tackle assessments can assist in identification of strengths and weaknesses in the tackle technique of individual players. Furthermore, the data from these tests may assist coaches to formulate defensive strategies specific to the abilities of their players.

10.3 Limitations

The limitations of individual studies are highlighted and discussed within the chapters of the thesis. The main limitation for this body of research was that all studies were conducted with only one rugby league club. The ability to conduct collaborative research among competing rugby league clubs is problematic. Some of the findings of this research may be influenced by relatively small sample sizes, individual player qualities, coaching philosophies or match-play strategies and tactics employed by the club. Therefore, while the findings provide an insight of how tackle characteristics, outcomes and abilities are related it may not be truly reflective of semi-professional players as a whole.

A further limitation may lie with the assessment of tackle ability through a one-on-one drill. It has been reported that most match-play rugby league tackles involve multiple defenders and only 18% of tackles are a one-on-one contest [21]. Furthermore the one-on-one tackle assessments utilised throughout this thesis does not involve any decision making by the defender (ie. the ball carrier runs directly at the defender with taking evasive action) and it does not assess the ability of the defender to bring the ball carrier to the ground. Due the aforementioned the one-on-one tackle assessment could be criticised for not being truly reflective of match-play rugby league tackling. While these short-comings of the one-on-one tackle assessment are valid, the findings in the studies conducted in this thesis and previous research has found the one-on-one tackle assessments to be related to match-play tackle performance.

Previous research examining rugby league tackling ability had concluded that better tacklers had superior acceleration over 10 metres and faster change of direction speed [13]. Additionally, playing experience is another variable that influences tackling ability [10, 16]. These variables and others, such as aerobic capacity and anthropometry could have been included but it was decided that it may detract from the primary focus of this research; to examine the influence of muscular strength and power on tackle ability and tackle performance in semi-professional rugby league players.

10.4 Future research

The research in this thesis was the first to investigate the relationships between tackling ability and strength and power, examine the interaction between tackle characteristics and tackle outcomes in rugby league, and assess tackle ability via the over-the-ball tackle assessment. To further advance our understanding of mechanisms that influence tackle

performance in rugby league the following recommendations on future research will potentially build upon the findings presented throughout this thesis:

1. All the research conducted in this thesis was conducted with semi-professional rugby league players thus its application to professional rugby league may be limited. The research themes investigated throughout this thesis should be replicated with professional rugby league players.
2. A major finding of this thesis was that changes in muscular strength was associated with changes in under-the-ball tackle ability. Future research should examine if changes in muscular strength and power are related to changes in over-the-ball tackle ability. Additionally, previous research has investigated how fatigue influenced under-the-ball tackling ability, it would be valuable to examine how fatigue effects the proficiency of the over-the-ball tackle assessment.
3. The relationships between tackle characteristics and tackle outcomes were examined in this thesis however, it did not explore if tackle characteristics differed between playing positions. Each playing position has unique defensive requirements which may dictate what tackle characteristics should be utilised to increase the likeliness of successful tackle outcomes. It is recommended that future research examine how match situations or playing position influences tackle characteristics and outcomes in rugby league players.

10.5 Summary

The overall purpose of this body of research was to enhance understanding of the elements that underpin tackle ability and tackle performance in rugby league players. The series of progressive studies undertaken as part of this thesis were the first to examine the associations between muscular strength and power measures and tackle ability, investigate the relationships between match-play tackle performance, tackle ability and physical qualities, and explore the practical utility of the over-the-ball tackle assessment. Collectively, the outcomes of the investigations documented in this thesis adds considerably to the literature on the rugby league tackle, and provides practical applications that are relevant to rugby league coaches, as well as strength and conditioning specialists working with collision sport athletes.

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Appendices

Appendix A - Evidence of Publications

Chapter 3

Speranza, Michael J. A., Gabbett T. J., Johnston, Rich D, Sheppard, Jeremy M. Muscular strength and power correlates of tackling ability in semi-professional rugby league players. *Journal Strength and Conditioning Research*. 2015; 29(8):2071- 2078.

MUSCULAR STRENGTH AND POWER CORRELATES OF TACKLING ABILITY IN SEMI-PROFESSIONAL RUGBY LEAGUE PLAYERS

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ABSTRACT

Speranza, MJA, Gabbett, TJ, Johnston, RD, and Sheppard, JM. Muscular strength and power correlates of tackling ability in semiprofessional rugby league players. *J Strength Cond Res* 29 (8): 2071–2078, 2015—This study investigated the relationship between muscular strength and power and tackling ability in semiprofessional rugby league players. Thirty-six semiprofessional (mean \pm SD age, 23.1 \pm 3.6 years) rugby league players, from 3 distinct playing divisions (first grade, second grade, and under 20s), underwent tests of upper-body strength (3 repetition maximum [RM] bench press), lower-body strength (3RM squat), upper-body power (plyometric push-up [PPU]), and lower-body power (countermovement jump). Muscular strength relative to body mass was also calculated. Tackling ability of the players was tested using video analysis of a standardized one-on-one tackling drill. For all players, the strongest correlates of tackling ability were squat ($r = 0.67$), bench press ($r = 0.58$), relative squat ($r = 0.41$), and PPU ($r = 0.56$). The strongest correlates of tackling ability in first grade players were squat ($r = 0.72$), bench press ($r = 0.72$), relative squat ($r = 0.86$), and PPU ($r = 0.70$). For second grade players, only relative squat ($r = 0.60$) and PPU ($r = 0.67$) were associated with tackling ability. The strongest correlates of tackling ability in under 20s players were squat ($r = 0.77$), bench press ($r = 0.70$), and PPU ($r = 0.65$). The findings of this study demonstrate that muscular strength and upper-body power contribute to tackling ability in semiprofessional rugby league players. Therefore, as long as the technical aspects of tackling technique are adequately coached and practiced, then enhancements in muscular strength and power may serve as foundational components to underpin improvement in tackling ability.

KEY WORDS defense, wrestle, contact, collision

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INTRODUCTION

Rugby league is a collision sport played internationally at junior and senior levels. The game is intermittent in nature, characterized by bouts of high-intensity running, collisions, and tackling, separated by periods of lower-intensity activity (25,34). The skill set required for rugby league is multifaceted with players requiring good ball handling ability (e.g., catching, passing, and kicking), quick and accurate decision making, and the ability to perform effective tackles (20). Rugby league players require well-developed aerobic fitness, speed, muscular strength and power, and agility to compete at an elite level (28). An understanding of how these physical qualities relate to specific rugby league skills is essential for the production of specific coaching, and strength and conditioning programs.

Rugby league players are subjected to multiple physical collisions throughout a match, most of which occur while players are defending (19,32). In defense, players are required to make contact and tackle opposition players to halt their forward progress. The number of tackles that players are required to make is dependent on playing position (22). Generally, forwards will perform an average of 39 tackles compared with the backs who perform an average of 16 tackles per match (22). A large part of success in a collision sport such as rugby league is based on tackling ability, the capacity to dominate the tackle contest, and the ability to tolerate physical impacts (8). Tackling technique as examined by a one-on-one tackling drill has been found to be strongly associated with the proportion of missed tackles (negative) and the proportion of dominant tackles (positive) that players complete during match-play (10). Therefore, the ability to perform a well-executed tackle is critical for the player to “win” the contact contest.

The majority of rugby league injuries occur during physical collisions and tackles (13,14). Studies have shown that up to 77.2% of all injuries occur during tackles, with 40% of these injuries occurring to the player performing the tackle (13–15,29). It has been proposed that poor tackling technique may be a significant risk factor for injury (23,30); however, there is limited evidence to support this claim (21).

Chapter 4

Speranza, Michael J. A., Gabbett T. J., Johnston, Rich D., Sheppard, Jeremy M. Effect of strength and power training on tackling ability in semi-professional rugby league players. *Journal Strength and Conditioning Research*. 2016; 30(2): 336-343.

EFFECT OF STRENGTH AND POWER TRAINING ON TACKLING ABILITY IN SEMI-PROFESSIONAL RUGBY LEAGUE PLAYERS

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ABSTRACT

Speranza, MJA, Gabbett, TJ, Johnston, RD, and Sheppard, JM. Effect of strength and power training on tackling ability in semiprofessional rugby league players. *J Strength Cond Res* 30(2): 336–343, 2016—This study examined the influence of a strength and power program on tackling ability in rugby league players. Twenty-four semiprofessional rugby league players (mean \pm SD age, 23.4 \pm 3.1 years) underwent tests of upper-body strength (3 repetition maximum [RM] bench press), lower-body strength (3RM squat), upper-body power (plyometric push-up), and lower-body power (countermovement jump [CMJ]). Muscular strength relative to body mass was also calculated. Tackling ability of the players was assessed using video analysis of a standardized one-on-one tackling drill. The players then underwent 8 weeks of strength and power training as part of their preseason training before being retested. Training resulted in significant ($p \leq 0.01$) improvements in absolute and relative measures of squat, bench press, CMJ peak power, and plyometric push-up peak power. The strongest correlates of change in tackling ability were changes in 3RM squat ($r = 0.60$; $p < 0.01$) and squat relative to body mass ($r = 0.54$; $p < 0.01$). The players with the greatest improvements in 3RM squat and squat relative to body mass (i.e., responders) had significantly greater improvements in tackling ability than nonresponding players ($p = 0.04$; effect size [ES] ≥ 0.85). A small, nonsignificant difference ($p = 0.20$; ES = 0.56) in tackling ability was found between responders and nonresponders for lower-body power. The findings of this study demonstrate that the enhancement of lower-body muscular strength, and to a lesser extent muscular power, contribute to improvements in tackling ability in semiprofessional rugby league players.

KEY WORDS tackle, defense, wrestle, contact, collision

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INTRODUCTION

Rugby league is a collision sport played internationally at junior and senior level. The game is intermittent in nature, characterized by bouts of high-intensity running, collisions, and tackling, separated by periods of lower intensity activity (14,18). The skill set required for rugby league is multifaceted with players requiring good ball handling ability (e.g., catching, passing, and kicking), quick and accurate decision making, and the ability to perform effective tackles (12). Rugby league players require well-developed aerobic fitness, speed, muscular strength and power, and agility to compete at an elite level (16). An understanding of how these physical qualities relate to specific rugby league skills is essential for the development of specific coaching, and strength and conditioning programs.

Rugby league players are subjected to multiple physical collisions throughout a match, most of which occur while players are defending (11,17). In defense, players are required to make contact and tackle opposition players to halt their forward progress. The number of tackles that players are required to make is dependent on playing position (13). Generally, forwards will perform an average of 39 tackles, compared with the backs who perform an average of 16 tackles per match (13). A large part of success in a collision sport such as rugby league is based on tackling ability, the capacity to dominate the tackle contest, and the ability to tolerate physical impacts (6). Tackling technique, as examined by a one-on-one tackling drill has been found to be strongly associated with the proportion of missed tackles (negative) and the proportion of dominant tackles (positive) that players complete during match-play (7). Therefore, the ability to perform a well-executed tackle is critical for the player to “win” the contact contest.

Several studies have examined the physiological and anthropometric correlates of tackling ability in subelite and professional rugby league players (8–10). Well-developed acceleration (over a 10-m sprint) and lower-body muscular power are associated with superior tackling ability in elite junior and professional rugby league players (8–10).

Chapter 5

Speranza, Michael J. A., Gabbett T. J., Greene, David A., Johnston, Rich D., Sheppard, Jeremy M. Changes in rugby league tackling ability during a competitive season: the relationship with strength and power qualities. *Journal Strength and Conditioning Research*. 2017; 31(12):3311- 3318.

CHANGES IN RUGBY LEAGUE TACKLING ABILITY DURING A COMPETITIVE SEASON: THE RELATIONSHIP WITH STRENGTH AND POWER QUALITIES

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ABSTRACT

Speranza, MJA, Gabbett, TJ, Greene, DA, Johnston, RD, and Sheppard, JM. Changes in rugby league tackling ability during a competitive season: the relationship with strength and power qualities. *J Strength Cond Res* 31(12): 3311–3318, 2017—This study examined the relationship between changes in tackling ability, and muscular strength and power during a semiprofessional rugby league competitive season. Twelve semiprofessional rugby league players (mean \pm SD age, 23.3 \pm 2.0 years) underwent tests of upper- and lower-body strength and power during the preseason period. Tackling ability was tested using video analysis of a standardized one-on-one tackling drill. Players repeated these tests after round 15 of a 25-match competitive season. Changes in 1 repetition maximum (1RM) squat ($r_s = 0.70$; $p < 0.02$) and squat relative to body mass ($r_s = 0.73$; $p < 0.01$) were significantly related to changes in tackling ability. Players with the greatest improvements in tackling ability (i.e., “responders”) retained 1RM squat (effect size, $ES = 0.85$, $p = 0.09$) and squat relative to body mass ($ES = 0.82$, $p = 0.15$) to a greater extent than the “nonresponders.” The results of this study suggest that players who retained lower-body strength were able to improve tackling ability during the competitive season, whereas reductions in lower-body strength were associated with decrements in tackling ability. This study highlights the importance of the development and maintenance of lower-body muscular strength for effective tackling performance throughout the rugby league season.

KEY WORDS tackle, defense, wrestle, contact, collision

INTRODUCTION

Rugby league is an intermittent, contact sport played internationally at junior and senior levels. The sport is physically demanding requiring players to have well-developed endurance, speed, agility, strength, and power to compete at an elite level (15). The sport is characterized by multiple physical contact efforts, known as the tackle contest. Gabbett et al. (11) reported that players were involved in 28–45 collisions per match with some players experiencing a physical contact once every 1.09 minutes during match-play. Thus, a large part of success in a contact sport such as rugby league is attributed to the ability to perform effective tackles, having a high tolerance for physical impacts, and the capacity to dominate the tackle contest (12).

In defense, players are required to make contact and tackle the opposition players to halt their forward progress. The number of tackles that players are required to make throughout a match is dependent on their playing position (13). During professional match-play, wide-running forwards make the greatest number of tackles with players in this position making an average of 25 tackles per match, with hit-up forwards, adjustables, and outside backs performing an average of 20, 15, and 8 tackles per match, respectively (10).

Most of the research examining tackling ability in rugby league has been performed using video analysis of a standardized one-on-one tackling drill. Tackling technique, as examined by the one-on-one tackle drill, has been found to be strongly associated with the proportion of missed tackles (negative) and proportion of dominant tackles (positive) performed in rugby league match-play (12,19). Studies examining the physiological and anthropometric correlates of tackling ability in rugby league players have concluded that high levels of acceleration (over a 10-meter sprint) and lower-body muscular power are associated with superior tackling ability in elite junior and professional rugby league players (7–9). Lower- and upper-body strength as well as upper-body power have been shown to be significantly related to tackling ability in semiprofessional rugby league players (18). Furthermore, it

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Chapter 6

Speranza, Michael J. A, Gabbett T. J, Johnston, Rich D, Sheppard, Jeremy M. Relationship between standardised tackling proficiency test and match-play tackle performance in semi-professional rugby league. *International Journal of Sports Physiology and Performance*. 2015; 10(6):754-760.

International Journal of Sports Physiology and Performance, 2015, 10, 754-760
<http://dx.doi.org/10.1123/Ijspp.2015-0044>
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Human Kinetics 
ORIGINAL INVESTIGATION

Relationship Between a Standardized Tackling Proficiency Test and Match-Play Tackle Performance in Semiprofessional Rugby League Players

Michael J.A. Speranza, Tim J. Gabbett, Rich D. Johnston, and Jeremy M. Sheppard

Purpose: This study examined the relationships between tackling ability, playing position, muscle strength and power qualities, and match-play tackling performance in semiprofessional rugby league players. **Methods:** Sixteen semiprofessional rugby league players (mean \pm SD age 23.8 ± 1.9 y) underwent tests for muscle strength and power. Tackling ability of the players was tested using video analysis of a standardized 1-on-1 tackling drill. After controlling for playing position, players were divided into “good tackler” or “poor tackler” groups based on the median split of the results of the 1-on-1 tackling drill. A total of 4547 tackles were analyzed from video recordings of 23 matches played throughout the season. **Results:** Maximal squat was significantly associated with tackling ability ($r_s = .71$, $P < .05$) and with the proportion of dominant tackles ($r_s = .63$, $P < .01$). Forwards performed more tackles ($P = .013$, $ES = 1.49$), with a lower proportion of missed tackles ($P = .03$, $ES = 1.38$) than backs. Good tacklers were involved in a larger proportion of dominant tackles and smaller proportion of missed tackles than poor tacklers. **Conclusions:** These findings demonstrate that lower-body strength contributes to more effective tackling performance during both a standardized tackling assessment and match play. Furthermore, players with good tackling ability in a proficiency test were involved in a higher proportion of dominant tackles and missed a smaller proportion of tackles during match play. These results provide further evidence of the practical utility of an off-field tackling assessment in supplying information predictive of tackling performance in competition.

Keywords: defense, wrestle, contact, collision, football, strength

Rugby league is a collision sport played internationally at junior and senior level, as an amateur, semiprofessional, or elite player. The game is intermittent in nature, characterized by bouts of high-intensity running, collisions, and tackling separated by periods of lower-intensity activity.^{1,2} The skill set required for rugby league is multifaceted, with players requiring good ball-handling ability (eg, catching, passing, carrying into contact, and kicking), quick and accurate decision making, and the ability to perform effective tackles.³ Rugby league players require well-developed aerobic fitness, speed, muscle strength and power, and agility to compete at an elite level.⁴ An understanding of how these physical qualities relate to specific rugby league skills is essential for the development of specific coaching and strength and conditioning programs.⁵

Rugby league players are involved in multiple physical collisions throughout a match, most of which occur while players are defending.^{6,7} In defense, players are required to make contact with and tackle opposition players to halt their forward progress. The number of tackles that players are required to make depends on playing position.⁸ Generally, forwards will perform an average of 26 tackles per match, compared with the backs, who perform an average of 11 tackles per match.⁸ A large part of success in a collision sport such as rugby league is based on tackling ability, the capacity to dominate the tackle contest, and the ability to tolerate

physical impacts.⁹ In previous research examining tackling ability, a standardized 1-on-1 tackling drill was developed to measure tackling technique in rugby league players. At a professional level, players who demonstrated poor tackling ability missed more tackles than players with superior tackling ability during match play. Similarly, players with good tackling ability were involved in a higher proportion of dominant tackles.¹⁰ Match tackling performance in the aforementioned study was limited to missed or dominant tackles. A more detailed analysis of match tackling performance would include off-loads conceded, positive defensive tackles (eg, forcing the opposition backward from the point of initial contact), or errors forced as the result of a tackle.

Several studies have examined the physiological and anthropometric correlates of tackling ability in subelite and professional rugby league players.^{11–13} Well-developed acceleration (over a 10-m sprint) and lower-body muscle power are associated with superior tackling ability in elite junior and professional rugby league players.^{11–13} Furthermore, lower- and upper-body strength, as well as upper-body power, have been shown to be significantly related to tackling ability in semiprofessional rugby league players.¹⁴ To date, no study has examined the relationship between physiological qualities and match-play tackling performance.

The purpose of this study was to examine the influence of muscle strength and power and of tackling ability on match-play tackling performance in semiprofessional rugby league players. This was achieved by investigating the relationship between tackling ability (as assessed using a standardized 1-on-1 tackle drill) and match-play tackling performance; determining the relationship between muscle strength and match-play tackling performance; examining the relationship between playing position, tackling

Speranza, Gabbett, and Johnston are with the School of Exercise Science, Australian Catholic University, Brisbane, Australia. Sheppard is with the School of Exercise and Health Sciences, Edith Cowan University, Perth, Australia. Address author correspondence to Michael Speranza at mjsper001@myacu.edu.au.

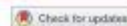
Chapter 7

Speranza, Michael J. A, Gabbett T. J, Greene, David A, Johnston, Rich D, Townshend, Andrew D. Tackle characteristics and outcomes in match-play rugby league: The relationship with tackle ability and physical qualities. *Science and Medicine in Football*. 2017; 1(3):265-271.

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ORIGINAL INVESTIGATION



Tackle characteristics and outcomes in match-play rugby league: the relationship with tackle ability and physical qualities

Michael J.A. Speranza^a, Tim J. Gabbett^{b,c}, David A. Greene^d, Rich D. Johnston^a and Andrew D. Townshend^a

^aSchool of Exercise Science, Australian Catholic University, Brisbane, Australia; ^bGabbett Performance Solutions, Brisbane, Australia; ^cInstitute for Resilient Regions, University of Southern Queensland, Ipswich, Australia; ^dSchool of Exercise Science, Australian Catholic University, Strathfield, Australia

ABSTRACT

Purpose: This study examined tackle characteristics and their relationships with match-play tackle outcomes, tackling ability, and physical qualities in rugby league players.

Methods: Fifteen rugby league matches were analysed, with the tackle characteristics and outcomes of 2355 tackle events coded. Muscle strength and power tests, and a standardized assessment of tackling ability were performed in 16 players.

Results: Medium body position, utilizing a shoulder or smother tackles, and producing leg drive upon contact decreased the odds of a missed tackle. Performing a front-on tackle, with a contact zone at the chest region reduced the odds of an offload. Tackling ability was significantly related to defenders moving forward prior to contact ($r_s = 0.60$, 95% CI 0.15–0.85, $P = 0.02$), front-on tackles ($r_s = 0.53$, 95% CI 0.05–0.81, $P = 0.04$), and displaying medium body height ($r_s = 0.57$, 95% CI 0.10–0.83, $P = 0.02$) in match-play tackles. Lower-body strength was significantly related to defenders exhibiting a medium body position ($r_s = 0.60$, 95% CI 0.15–0.85, $P = 0.01$) and the ball-carrier being placed on their back ($r_s = 0.72$, 95% CI 0.35–0.90, $P = 0.002$).

Conclusion: The findings suggest that match-play tackle performance is related to both tackle characteristics and physical qualities.

ARTICLE HISTORY

Accepted 14 June 2017

KEYWORDS

Defence; wrestle; contact; collision; strength

Introduction

The ability to control and dominate the tackle contest is one of the most important components for success in contact sports such as rugby league or rugby union (Gabbett and Kelly 2007; Rooyen et al. 2014). Successful teams concede fewer metres in defence (Gabbett 2014) and are involved in fewer “ineffective” tackles than unsuccessful teams (Rooyen et al. 2014). Anecdotally, the ability to control the ruck (i.e., play-the-ball speed) is considered an important factor for rugby league success (Gabbett and Kelly 2007). A greater understanding of tackle characteristics and the physical qualities of players that can influence tackle outcomes is critical from a performance perspective.

Previous research examining rugby league match-play tackles identified or characterized tackles by player position, direction in which contact is made and contact zone (King et al. 2010; Austin et al. 2011). King et al. (2010) reported that the hip and thigh or mid-torso region was the most common contact zone, with contact made most commonly from behind the visual field of the ball-carrier and involving two or three defenders. Austin et al. (2011) found that the first defender was most likely to make a front-on tackle, either low or high, a second player generally performed a front-on high tackle, and if a third player became involved, their contact was most likely to be from the side and above the waist. Although these studies provide a good description of the most common

tackle characteristics in rugby league match-play, they do not identify how these characteristics influence tackle outcomes such as successful, missed, or dominate tackles.

In previous research focusing on tackling ability, a standardized one-on-one tackling drill has been used to quantify tackle technique in rugby league players (Gabbett and Ryan 2009; Speranza et al. 2015b). At a professional level, players who demonstrated poor tackling ability missed more tackles during match-play than players with superior tackling ability (Gabbett and Ryan 2009). Players with good tackling ability were involved in a greater proportion of dominant tackles (Gabbett and Ryan 2009). Similarly, semi-professional players with good tackling ability on a standardized proficiency test were involved in a greater proportion of dominant tackles and missed a smaller proportion of tackles during match-play (Speranza et al. 2015b). These studies have highlighted the association between tackling technique and match-play performance; however, the studies have not investigated whether this association is due to differences in tackle characteristics during match-play.

Lower- and upper-body muscular strength as well as upper-body power have been shown to be significantly related to tackling ability, as quantified by a standardized one-on-one tackle test, in semi-professional rugby league players (Speranza et al. 2015a; Gabbett Fothcoming 2016). Furthermore, greater lower-body strength as measured by

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Chapter 8

Speranza, Michael J. A, Gabbett T. J, Greene, David A, Johnston, Rich D, Townshend, Andrew D. An alternate test of tackling ability in rugby league players. *International Journal of Sports Physiology and Performance*. 2018; 13(3):347-352

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ORIGINAL INVESTIGATION

An Alternative Test of Tackling Ability in Rugby League Players

Michael J.A. Speranza, Tim J. Gabbett, David A. Greene, Rich D. Johnston,
Andrew D. Townshend, and Brett O'Farrell

This study investigated the relationship between 2 tests of tackling ability, muscle strength, and power in semiprofessional rugby league players. Thirty-one players, 19 first-grade and 12 second-grade, underwent tests of muscle strength (1-repetition-maximum bench press, chin-up, and squat) and power (plyometric push-up and countermovement jump). Tackling ability was assessed via video analysis of under-and over-the-ball tackle drills. The first-grade players had significantly greater scores in both the under-the-ball ($P = .03$, effect size [ES] = 0.84, 95% CI 0.07–1.50) and over-the-ball tackling-ability tests ($P < .001$, ES = 1.86, 95% CI 0.83–2.52) than the second-grade players. A large, significant relationship was found between under- and over-the-ball tackling ability ($r = .55$, 95% CI .24–.76, $P = .001$). Lower-body strength ($r = .37$, 95% CI .02–.64, $P = .04$) was moderately associated with under-the-ball tackling ability, whereas over-the-ball tackling ability was moderately associated with plyometric push-up performance ($r = .39$, 95% CI .04–.65, $P = .03$). This study found that over-the-ball tackling ability was significantly associated with under-the-ball tackling in semiprofessional rugby league players. Furthermore, it was found that, compared with the second-grade players, the first-grade players had superior tackle ability in both tackle drills. In this study it was observed that plyometric push-up peak power was significantly related to over-the-ball tackling ability and absolute lower-body strength was associated with under-the-ball tackling ability. These findings provide skill coaches and strength and conditioning staff a greater understanding of elements that contribute to effective tackling ability.

Keywords: defense, wrestle, contact, collision, strength, power

The ability to execute proficient and effective tackles is a critical skill for success in collision sports such as rugby league or rugby union.^{1,2} Recent studies have suggested that proficient tackle ability may play a role in the prevention of injury and concussions.^{3,4} Furthermore, it has been shown that winning teams concede fewer meters in defense and are involved in fewer “ineffective” tackles than losing teams.^{2,5} Previous research examining tackling ability through the analysis of a standardized 1-on-1 tackling drill, where contact is made at the torso of the ball carrier, has been used to quantify tackle technique in rugby league players.^{6–8} At a professional and semiprofessional level, players who demonstrated superior tackling ability missed a smaller proportion of tackles and performed a greater proportion of dominant tackles during match play than players with poor tackling ability.^{6,7}

A study documenting tackle characteristics in the 2008 Australian National Rugby League competition found that the majority of tackles were performed at the midtorso of the ball carrier.⁹ However, a more recent study investigating tackling ability in semiprofessional rugby league match play found that approximately 70% of tackles were executed around the ball carrier's chest and shoulders and fewer than 25% of tackles were made at the torso region.⁷ A reason for the change in tackle height may be due to an increased priority placed on players to stop the ball carrier from passing or off-loading the football. The

likelihood of an off-load is decreased when the initial contact zone was at the chest and shoulders compared with contact at the torso or legs.¹⁰ Tackles made at the shoulder and chest region are commonly referred to as over-the-ball or smother tackles. It has been found that the smother tackle was as likely to have successful outcomes in rugby league and rugby union match play as the traditional shoulder tackle.^{10,11} Players' ability to perform a traditional shoulder tackle may not reflect their ability to tackle over the ball, and given the high frequency of over-the-ball tackles, it appears important to assess this ability in a specific drill to determine whether it is a distinct skill to under-the-ball tackles.

Several studies have examined the physiological and anthropometric correlates of tackling ability in subelite and professional rugby league players.^{12–15} Well-developed acceleration (over a 10-m sprint) and lower-body muscle power were associated with superior tackling ability in elite junior and professional rugby league players.^{12–14} Furthermore, maximal squat and bench press, as well as peak power of a plyometric push-up (PPU), have been shown to be significantly related to tackling ability in semiprofessional rugby league players.¹⁵ Studies investigating tackling ability in rugby league have only used a standardized 1-on-1 tackle drill where contact is made under the ball of the ball carrier. Given that the majority of the tackles made in match play are over-the-ball tackles, an investigation into the physiological correlates of an alternative tackling-ability drill was warranted.

The purpose of this study was to investigate an alternative 1-on-1 tackling drill where contact is made at the chest and shoulder region of the ball carrier (ie, an over-the-ball tackle). This study compared the results between the under-the-ball and over-the-ball tackle drills, compared tackling abilities between higher- and lower-skilled rugby league players, and investigated the relationship between muscle-strength and -power qualities and tackling ability in both drills.

Speranza, Johnston, and Townshend are with the School of Exercise Science, Australian Catholic University, Brisbane, Australia. Gabbett is with the Gabbett Performance Solutions, Brisbane, Australia, and the Inst for Resilient Regions, University of Southern Queensland, Ipswich, Australia. Greene is with the School of Exercise Science, Australian Catholic University, Strathfield, Australia. O'Farrell is with the Parramatta Eels Rugby League Football Club, Parramatta, Australia. Speranza (mjsper001@myacu.edu.au) is corresponding author.

Chapter 9

Speranza, Michael J. A, Gabbett T. J, Greene, David A, Johnston, Rich D, Townshend, Andrew D. Relationship between Two Standardised Tackling Proficiency Tests and Rugby League Match-Play Tackle Performance. *International Journal of Sports Physiology and Performance*. 2017. Doi: 10.1123/ijsp.2017-0593

International Journal of Sports Physiology and Performance - Decision on Manuscript ID IJSPP.2017-0593.R1

International Journal of Sports Physiology and Performance <onbehalf+ralph.beneke+staff.uni-marburg.de@manusc

Mon 30/10/2017 5:37 PM

To:mjsper001@myacu.edu.au <mjsper001@myacu.edu.au>; m.speranza@hotmail.com <m.speranza@hotmail.com>;

30-Oct-2017

Dear Mr. Speranza,

It is a pleasure to accept your manuscript entitled "Relationship Between Two Standardized Tackling Proficiency Tests and Rugby League Match-Play Tackle Performance" in its current form for publication in the International Journal of Sports Physiology and Performance. The comments of the reviewers who reviewed your manuscript are included at the foot of this letter.

The In Press and MedLine listings should be available approximately 4 weeks from now.

Thank you for your fine contribution. On behalf of the Editors of the International Journal of Sports Physiology and Performance, we look forward to your continued contributions to the Journal.

Yours sincerely,

Prof. Ralph Beneke MD PhD FACSM
Editor, International Journal of Sports Physiology and Performance

Appendix B - Ethics Approval

Michael Speranza

From: Kylie Pashley <Kylie.Pashley@acu.edu.au> on behalf of Res Ethics <Res.Ethics@acu.edu.au>
Sent: Wednesday, 16 January 2013 4:28 PM
To: Tim Gabbett; Michael Speranza
Cc: Kylie Pashley
Subject: 2013 01Q Ethics application approved!

Dear Applicant,

Principal Investigator: Dr Timothy James Gabbett Student Researcher: Mr Michael Speranza Ethics Register Number: 2013 01Q Project Title: Influence of Strength and Power Qualities on Tackling Ability in Rugby League Risk Level: Low Risk 2 Date Approved: 16/01/2013 Ethics Clearance End Date: 30/06/2013

This email is to advise that your application has been reviewed by the Australian Catholic University's Human Research Ethics Committee and confirmed as meeting the requirements of the National Statement on Ethical Conduct in Human Research.

This project has been awarded ethical clearance until 30/06/2013. In order to comply with the National Statement on Ethical Conduct in Human Research, progress reports are to be submitted on an annual basis. If an extension of time is required researchers must submit a progress report.

Whilst the data collection of your project has received ethical clearance, the decision and authority to commence may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance or permissions from other organisations to access staff. Therefore the proposed data collection should not commence until you have satisfied these requirements.

If you require a formal approval certificate, please respond via reply email and one will be issued.

Decisions related to low risk ethical review are subject to ratification at the next available Committee meeting. You will only be contacted again in relation to this matter if the Committee raises any additional questions or concerns.

Researchers who fail to submit an appropriate progress report may have their ethical clearance revoked and/or the ethical clearances of other projects suspended. When your project has been completed please complete and submit a progress/final report form and advise us by email at your earliest convenience. The information researchers provide on the security of records, compliance with approval consent procedures and documentation and responses to special conditions is reported to the NHMRC on an annual basis. In accordance with NHMRC the ACU HREC may undertake annual audits of any projects considered to be of more than low risk.

It is the Principal Investigators / Supervisors responsibility to ensure that:

1. All serious and unexpected adverse events should be reported to the HREC with 72 hours.
2. Any changes to the protocol must be approved by the HREC by submitting a Modification Form prior to the research commencing or continuing.
3. All research participants are to be provided with a Participant Information Letter and consent form, unless otherwise agreed by the Committee.

For progress and/or final reports, please complete and submit a Progress / Final Report form:
www.acu.edu.au/465013

For modifications to your project, please complete and submit a Modification form:
www.acu.edu.au/465013

Researchers must immediately report to HREC any matter that might affect the ethical acceptability of the protocol eg: changes to protocols or unforeseen circumstances or adverse effects on participants.

Please do not hesitate to contact the office if you have any queries.

Kind regards,
Kylie Pashley

Ethics Officer | Research Services
Office of the Deputy Vice Chancellor (Research) Australian Catholic University

Appendix C - Information Letters and Consent Forms

Chapters 3 and 4

PARTICIPANT INFORMATION LETTER

PROJECT TITLE: Influence of Strength and Power Qualities on Tackling Ability in Rugby League

PRINCIPAL INVESTIGATOR: Tim Gabbett (PhD)

STUDENT RESEARCHER: Michael Speranza

STUDENT'S DEGREE: Master of Exercise Science

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

Acceleration over a 10-metre sprint and lower body power have been shown to be strongly correlated with superior tackling ability. Although maximal muscular strength and power has been shown to discriminate between elite and sub-elite rugby league players, no study has examined the influence of upper and lower limb muscular strength on tackling performance, nor has any study examined if improvements in muscular strength and power transfer to improvements in tackling proficiency.

The proposed two part study will firstly examine the tackling ability of sub-elite rugby league players and investigate the relationship between muscular strength and power qualities and tackling proficiency in these players. Part two of the study will investigate the effect that an 8-week strength and power program has on tackling ability in sub-elite rugby league players.

Who is undertaking the project?

This project is being conducted by Dr Tim Gabbett and Michael Speranza will form the basis for the degree of Master of Exercise Science at Australian Catholic.

Are there any risks associated with participating in this project?

There are no additional risks in participation to those that exist in normal training sessions. It is advised that during the tackling drills you wear protective equipment.

What will I be asked to do?

Over an eight week period you will be required to undergo a series of strength, power and tackling tests. The tests include:

- 3 repetition maximum of the bench press and the full squat. These exercises will be performed with free weights. You will be required to warm up with a light load and progressively increase the load until the maximal weight that can be lifted for 3 consecutive times.
- Counter-movement jump and plyometric push up performed on a force platform. You will be required to perform 3 repetitions with no additional load.
- A standardised one-on-one tackling drill in a 10 meter grid. Video footage will be taken of this drill. The tackling drill involves a "defending" player attempting to

perform a head on tackle of an "attacking" player. The defending player will complete 6 repeat efforts of the drill.

- Perform an 8-week strength and training program that will form part of your preseason training.
- The location of the study will be at North Brisbane Rugby League Clubs training facilities at Wavell State High School.

How much time will the project take?

Testing and training will be part of your regular training and will occur throughout the football clubs preseason training sessions. Attendance outside of training times will not be required.

What are the benefits of the research project?

The findings from this study will provide information to coaches on the skill and physical qualities that are most relevant to sub-elite rugby league performance.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. Withdrawal from the study will not affect your rights or position within the club.

Will anyone else know the results of the project?

All data collected will be partially de-identified when downloading it to a password-locked computer. Video footage will be stored on the same computer. All data relating to this project will be stored in a locked filing cabinet. All findings and results of this study will remain confidential (disclosed only within the club, participants and investigators) and when published, participants will not be identified.

Northern Suburbs Rugby league Football Club coaching staff and participants will have access to unidentifiable data to provide generalized coaching and development of participants. Permission to review data will be granted by Dr Tim Gabbett.

Will I be able to find out the results of the project?

You will be able to find out your individual data and the averages for the group upon request.

Who do I contact if I have questions about the project?

If you have any questions regarding the study you can contact Michael Speranza on the details below.

Phone: 0400601980

Email: msper001@myacu.edu.au

What if I have a complaint or any concerns?

The study has been approved by the Human Research Ethics Committee at Australian Catholic University (approval number 2013 01Q). If you have any complaints or concerns about the conduct of the project, you may write to the Chair of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).

Chair, HREC

c/o Office of the Deputy Vice Chancellor (Research)
Australian Catholic University
Melbourne Campus
Locked Bag 4115
FITZROY, VIC, 3065
Ph: 03 9953 3150
Fax: 03 9953 3315
Email: res.ethics@acu.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want to participate! How do I sign up?

Please inform Michael Speranza in person or via email or phone and complete the informed consent form.

Yours sincerely,

Dr Tim Gabbett
Principal Investigator

Michael Speranza
Student Investigator

CONSENT FORM

TITLE OF PROJECT: Influence of Strength and Power Qualities on Tackling Ability in Rugby League

The study has been approved by the Human Research Ethics Committee at Australian Catholic University – Approval number 2013 01Q.

PRINCIPAL INVESTIGATOR: Tim Gabbett (PhD)

STUDENT RESEARCHER: Michael Speranza

PROGRAM ENROLLED: Master of Exercise Science

I..... (*the participant*) have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this 8-week study and participate in strength and power testing, strength training, and a videotaped tackling drill, realising that I can withdraw my consent at any time without adverse consequences. I am aware that the testing and training program will be part of my regular training program for the rugby league club. I understand that all participation of this study will occur during scheduled training sessions with the North Brisbane Rugby League Club and will not require any other involvement outside those times. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT:

SIGNATURE

DATE

.....

SIGNATURE OF RESEARCHER:

DATE:.....

Chapter 5

PARTICIPANT INFORMATION LETTER

PROJECT TITLE: Influence of Strength and Power Qualities on Tackling Ability in Rugby League During a Competitive Season

PRINCIPAL INVESTIGATOR: Tim Gabbett (PhD)

STUDENT RESEARCHER: Michael Speranza

STUDENT'S DEGREE: PhD

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

The study will investigate influence muscular strength and power has on tackling ability during a competitive season in sub-elite rugby league players.

Who is undertaking the project?

This project is being conducted by Dr Tim Gabbett and Michael Speranza. The research is for a PhD project and will be part of a thesis.

Are there any risks associated with participating in this project?

There are no additional risks in participation to those that exist in normal training sessions. It is advised that during the tackling drills you wear protective equipment.

What will I be asked to do?

You will be required to undergo a series of strength, power and tackling tests. The tests include:

- 1 repetition maximum of the bench press and the full squat. These exercises will be performed with free weights. You will be required to warm up with a light load and progressively increase the load until the maximal weight that can be lifted.
- Counter-movement jump and plyometric push up performed on a force platform. You will be required to perform 3 repetitions with no additional load.
- A standardised one-on-one tackling drill in a 10 meter grid. Video footage will be taken of this drill. The tackling drill involves a "defending" player attempting to perform a head on tackle of an "attacking" player. The defending player will complete 6 repeat efforts of the drill.
- The location of the study will be at North Brisbane Rugby League Clubs training facilities at Wavell State High School.

How much time will the project take?

Testing and training will be part of your regular training and will occur throughout the football clubs preseason training sessions. Attendance outside of training times will not be required.

What are the benefits of the research project?

The findings from this study will provide information to coaches on the skill and physical qualities that are most relevant to sub-elite rugby league performance.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. Withdrawal from the study will not affect your rights or position within the club.

Will anyone else know the results of the project?

All data collected will be partially de-identified when downloading it to a password-locked computer. Video footage will be stored on the same computer. All data relating to this project will be stored in a locked filing cabinet. All findings and results of this study will remain confidential (disclosed only within the club, participants and investigators) and when published, participants will not be identified.

Northern Suburbs Rugby league Football Club coaching staff and participants will have access to unidentifiable data to provide generalized coaching and development of participants. Permission to review data will be granted by Dr Tim Gabbett.

Will I be able to find out the results of the project?

You will be able to find out your individual data and the averages for the group upon request.

Who do I contact if I have questions about the project?

If you have any questions regarding the study you can contact Michael Speranza on the details below.

Phone: 0400601980

Email: msper001@myacu.edu.au

What if I have a complaint or any concerns?

The study has been approved by the Human Research Ethics Committee at Australian Catholic University (approval number 2013 01Q). If you have any complaints or concerns about the conduct of the project, you may write to the Chair of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).

Chair, HREC
c/o Office of the Deputy Vice Chancellor (Research)
Australian Catholic University
Melbourne Campus
Locked Bag 4115
FITZROY, VIC, 3065
Ph: 03 9953 3150
Fax: 03 9953 3315
Email: res.ethics@acu.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want to participate! How do I sign up?

Please inform Michael Speranza in person or via email or phone and complete the informed consent form.

Yours sincerely,

Dr Tim Gabbett

Principal Investigator

Michael Speranza

Student Investigator

CONSENT FORM

TITLE OF PROJECT: Influence of Strength and Power Qualities on Tackling Ability in Rugby League During a Competitive Season

The study has been approved by the Human Research Ethics Committee at Australian Catholic University – Approval number 2013 01Q.

PRINCIPAL INVESTIGATOR: Tim Gabbett (PhD)

STUDENT RESEARCHER: Michael Speranza

PROGRAM ENROLLED: Master of Exercise Science

I..... (*the participant*) have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this study and participate in strength and power testing, strength training, and a videotaped tackling drill, realising that I can withdraw my consent at any time without adverse consequences. I am aware that the testing and training program will be part of my regular training program for the rugby league club. I understand that all participation of this study will occur during scheduled training sessions with the North Brisbane Rugby League Club and will not require any other involvement outside those times. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT:

SIGNATURE

DATE

.....

SIGNATURE OF RESEARCHER:

DATE:.....

Chapters 6 and 7

PARTICIPANT INFORMATION LETTER

PROJECT TITLE: Tackling ability, physical qualities and match-play tackle performance

PRINCIPAL INVESTIGATOR: Tim Gabbett (PhD)

STUDENT RESEARCHER: Michael Speranza

STUDENT'S DEGREE: PhD

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

It is generally accepted that high levels of strength and power is advantageous for rugby league players to be successful in the tackle contest. The purpose of this study is to investigate the relationships between tackling ability, muscular strength and power qualities and match-play tackling performance.

Who is undertaking the project?

This project is being conducted by Dr Tim Gabbett and Michael Speranza. The research is for a PhD project and will be part of a thesis.

Are there any risks associated with participating in this project?

There are no additional risks in participation to those that exist in normal training sessions. It is advised that during the tackling drills you wear protective equipment.

What will I be asked to do?

You will be required to undergo a series of strength, power and tackling tests. The tests include:

- Evaluation of maximal strength of the bench press and the full squat. These exercises will be performed with free weights. You will be required to warm up with a light load and progressively increase the load until the maximal weight that can be lifted.
- Counter-movement jump and plyometric push up performed on a force platform. You will be required to perform 3 repetitions with no additional load.
- A standardised one-on-one tackling drill in a 10 meter grid. Video footage will be taken of this drill. The tackling drill involves a "defending" player attempting to perform a head on tackle of an "attacking" player. The defending player will complete 6 repeat efforts of the drill.
- The location of the study will be at North Brisbane Rugby League Clubs training facilities.

How much time will the project take?

Testing and training will be part of your regular training and will occur throughout the football clubs preseason training sessions. Attendance outside of training times will not be required.

What are the benefits of the research project?

The findings from this study will provide information to coaches on the skill and physical qualities that are most relevant to sub-elite rugby league performance.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. Withdrawal from the study will not affect your rights or position within the club.

Will anyone else know the results of the project?

All data collected will be partially de-identified when downloading it to a password-locked computer. Video footage will be stored on the same computer. All data relating to this project will be stored in a locked filing cabinet. All findings and results of this study will remain confidential (disclosed only within the club, participants and investigators) and when published, participants will not be identified.

Northern Suburbs Rugby league Football Club coaching staff and participants will have access to unidentifiable data to provide generalised coaching and development of participants. Permission to review data will be granted by Dr Tim Gabbett.

Will I be able to find out the results of the project?

You will be able to find out your individual data and the averages for the group upon request.

Who do I contact if I have questions about the project?

If you have any questions regarding the study you can contact Michael Speranza on the details below.

Phone: 0400601980

Email: msper001@myacu.edu.au

What if I have a complaint or any concerns?

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Chair, HREC

c/o Office of the Deputy Vice Chancellor (Research)

Australian Catholic University

Melbourne Campus

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I want to participate! How do I sign up?

Please inform Michael Speranza in person or via email or phone and complete the informed consent form.

Yours sincerely,

Dr Tim Gabbett

Principal Investigator

Michael Speranza

Student Investigator

CONSENT FORM

TITLE OF PROJECT: Tackling ability, physical qualities and match-play tackle performance

The study has been approved by the Human Research Ethics Committee at Australian Catholic University – Approval number 2013 01Q.

PRINCIPAL INVESTIGATOR: Tim Gabbett (PhD)

STUDENT RESEARCHER: Michael Speranza

I..... (*the participant*) have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this study and participate in strength and power testing, and a videotaped tackling drill, realising that I can withdraw my consent at any time without adverse consequences. I am aware that the testing and training program will be part of my regular training program for the rugby league club. I understand that all participation of this study will occur during scheduled training sessions with the North Brisbane Rugby League Club and will not require any other involvement outside those times. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT:

SIGNATURE

DATE

.....

SIGNATURE OF RESEARCHER:

DATE:.....

Chapters 8 and 9

PARTICIPANT INFORMATION LETTER

PROJECT TITLE: An alternate tackling drill – The over-the-ball assessment

PRINCIPAL INVESTIGATOR: Tim Gabbett (PhD)

STUDENT RESEARCHER: Michael Speranza

STUDENT'S DEGREE: PhD

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

Previous research has examined the traditional shoulder tackle, demonstrating that the assessment was related to match-play tackle performance. However, there has been an increased focus on player to perform a smother or over-the-ball tackle. The purpose of this study is to investigate the relationships between the two different types of tackling ability test, associations to muscular strength and power qualities, and examine if the drills are related to match-play tackling performance.

Who is undertaking the project?

This project is being conducted by Dr Tim Gabbett and Michael Speranza. The research is for a PhD project and will be part of a thesis.

Are there any risks associated with participating in this project?

There are no additional risks in participation to those that exist in normal training sessions. It is advised that during the tackling drills you wear protective equipment.

What will I be asked to do?

You will be required to undergo a series of strength, power and tackling tests. The tests include:

- Evaluation of maximal strength of the bench press, chin up and the full squat. These exercises will be performed with free weights. You will be required to warm up with a light load and progressively increase the load until the maximal weight that can be lifted.
- Counter-movement jump and plyometric push up performed on a force platform. You will be required to perform 3 repetitions with no additional load.
- A standardised one-on-one tackling drill in a 10 meter grid. Video footage will be taken of this drill. Two tackling drills will be performed. They involve a "defending" player attempting to perform a head on tackle of an "attacking" player. The defending player will complete 6 repeat efforts of each drill.
- The location of the study will be at North Brisbane Rugby League Clubs training facilities.

How much time will the project take?

Testing and training will be part of your regular training and will occur throughout the football clubs preseason training sessions. Attendance outside of training times will not be required.

What are the benefits of the research project?

The findings from this study will provide information to coaches on the skill and physical qualities that are most relevant to sub-elite rugby league performance.

Can I withdraw from the study?

Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences. Withdrawal from the study will not affect your rights or position within the club.

Will anyone else know the results of the project?

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Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

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Yours sincerely,

Dr Tim Gabbett
Principal Investigator

Michael Speranza
Student Investigator

CONSENT FORM

TITLE OF PROJECT: An alternate tackling drill – The over-the-ball assessment

PRINCIPAL INVESTIGATOR: Tim Gabbett (PhD)

STUDENT RESEARCHER: Michael Speranza

I..... (*the participant*) have read and understood the information provided in the Letter to Participants. Any questions I have asked have been answered to my satisfaction. I agree to participate in this study and participate in strength and power testing, and 2 videotaped tackling drills, realising that I can withdraw my consent at any time without adverse consequences. I am aware that the testing and training program will be part of my regular training program for the rugby league club. I understand that all participation of this study will occur during scheduled training sessions with the North Brisbane Rugby League Club and will not require any other involvement outside those times. I agree that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way.

NAME OF PARTICIPANT:

SIGNATURE

DATE

.....

SIGNATURE OF RESEARCHER:

DATE:.....