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Original Investigation

An alternate test of tackling ability in rugby league players

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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.

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

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.[1, 2] Recent studies have suggested that proficient tackle ability may play a role in the prevention or injury and concussions.[3, 4] Furthermore is has been shown that winning teams concede fewer metres in defence and are involved in fewer 'ineffective' tackles than losing teams.[2, 5] Previous research examining tackling ability through the analysis of a standardized 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.[6-8] 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.[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 mid torso of the ball-carrier.[9] 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.[7] 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.[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 compared to the traditional shoulder tackle.[10, 11] 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.[12-15] 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.[12-14] 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.[15] Existing research investigating tackling ability in rugby league have only used a standardized 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.

METHODS

Participants

Thirty-one semi-professional rugby league players (mean ± 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 standardized 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.[6, 7, 12] 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 standardized 1-on-1 defensive drill in previous studies.[12-14] 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 1.

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 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.[15, 16] 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.[17] To minimize 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.[18] 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.[19]

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.[20] 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.[21] 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.[21] The level of significance was set at $P < 0.05$.

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 1).

The results of the standardized tackling tests for the first and second grade players are shown in Table 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 4 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 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, $P = 0.031$).

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 standardized tackle drill. Leg drive has been a criteria for assessing rugby league one-on-one tackle ability in multiple studies.[6, 7, 12] This finding supports recent research which found that leg drive was significantly associated with tackle success in rugby union match-play.[10] 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.[12, 14, 15, 22] 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.[6, 7] 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,[7, 15, 23] 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.[24, 25] Furthermore, it has been shown that players with greater relative lower-body strength had greater under-the-ball tackling ability under fatigued conditions.[23] Collectively, the findings of these studies suggest that lower-body strength is an important contributor to under-the-ball tacking 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.[15] In rugby league, body mass has been shown to be a critical component in the production of momentum in collision events.[26] 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 coefficient of determination (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.[7]

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.

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.

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REFERENCES

1. Gabbett T, Kelly J. Does fast defensive line speed influence tackling proficiency in collision sport athletes. *International Journal of Sports Science and Coaching*. 2007;2(4):467-472.

2. Rooyen Mv, Yasin N, Viljoen W. Characteristics of an 'effective' tackle outcome in Six Nations rugby. *European Journal of Sport Science*. 2014;14(2):123-129.

3. Hendricks S, O'connor S, Lambert M, Brown J, Burger N, Mc Fie S, Readhead C, Viljoen W. Contact technique and concussions in the South African under-18 Coca-Cola Craven Week Rugby tournament. *European Journal of Sport Science*. 2015;15(6):557-564.

4. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle technique and tackle-related injuries in high-level South African Rugby Union under-18 players: real-match video analysis. *British Journal of Sports Medicine*. 2016;50(15):932-938.

5. Gabbett TJ. Effects of physical, technical, and tactical factors on final ladder position in semiprofessional rugby league. *International Journal of Sports Physiology and Performance*. 2014;9(4):680-8.

6. Gabbett TJ, Ryan P. Tackling technique, injury risk, and playing performance collision sport athletes. *International Journal of Sports Science and Coaching*. 2009;4(4):521-533.

7. Speranza MJ, Gabbett TJ, Johnston RD, Sheppard JM. Relationship Between a Standardized Tackling Proficiency Test and Match-Play Tackle Performance in Semiprofessional Rugby League Players. *International Journal of Sports Physiology & Performance*. 2015;10(6):754-760.

8. Gabbett TJ. Influence of fatigue on tackling technique in rugby league players. *Journal of Strength and Conditioning Research*. 2008;22(2):625-632.

9. King D, Hume PA, Clark T. Video analysis of tackles in professional rugby league matches by player position, tackle height and tackle location. *International Journal of Performance Analysis in Sport*. 2010;10(3):241-254.

10. Hendricks S, Mathews B, Roode B, Lambert M. Tackler characteristics associated with tackle performance in rugby union. *European Journal of Sport Science*. 2014;14(8):753 - 762.

11. Speranza MJA, Gabbett TJ, Greene DA, Johnston RD, Townshend AD. Relationships between player qualities, tackle characteristics, and tackle outcomes in rugby league. *Science and Medicine in Football*. 2017;In Press.

12. Gabbett TJ, Jenkins DG, Abernethy B. Correlates of tackling ability in high-performance rugby league players. *Journal of Strength and Conditioning Research*. 2011;25(1):72-80.

13. Gabbett TJ. Physiological and anthropometic correlates of tackling ability in rugby league players. *J Strength Cond Res*. 2009;23(2):540-548.

14. Gabbett TJ, Jenkins DG, Abernethy B. Physiological and anthropometric correlates of tackling ability in junior elite and subelite rugby league players. *J Strength Cond Res*. 2010;24(11):2989-2995.

15. Speranza MJ, Gabbett TJ, Johnston RD, Sheppard JM. Muscular strength and power correlates of tackling ability in semi-professional rugby league players. *Journal of Strength and Conditioning Research*. 2015;29(8):2071-2078.

16. Johnston RD, Gabbet TJ, Seibold AJ, Jenkins DG. Influence of physical contact on neuromuscular fatigue and markers of muscle damage following small-sided games. *Journal of Science and Medicine in Sport*. 2014;17(5):535-540.

17. Ran W, Hoffman JR, Sadres E, Bartolomei S, Muddle TWD, Fukuda DH, Stout JR. Evaluating upper-body strength and power from a single test:The ballistic push-up. *Journal of Strength & Conditioning Research*. 2017;31(5):1338-1345.

18. Australian Sports Commission, *National protocols for the assessment of strength and power*, Australian Sports Commission, Editor. 2007.

19. Hopkins WG. Measures of reliability in sports medicine and science. *Sports Medicine*. 2000;30(1):1-15.

20. Cohen J. *Statistical Power Analysis for the Behavioural Sciences*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.

21. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*. 2009;41(1):3-13.

22. Gabbett T, Ryan P. Tackling technique, injury risk, and playing performance collision sport athletes. *Int J Sports Sci Coach*. 2009;4(4):521-533.

23. Gabbett TJ. Influence of Fatigue on Tackling Ability in Rugby League Players: Role of Muscular Strength, Endurance, and Aerobic Qualities. *PloS One*. 2016;In Press.

24. Speranza MJA, Gabbett TJ, Johnston RD, Sheppard JM. The effect of strength and power training on tackling ability in semi-professional rugby league players. *Journal of Strength and Conditioning Research*. 2016;30(2):336-343.

25. Speranza M, Gabbett TJ, Greene DA, Johnston RD, Sheppard JM. Changes in rugby league tackling ability during a competitive season: the relationship with strength and power qualities. *Journal of Strength & Conditioning Research*. 2016;In press.

26. Baker DG, Newton RU. Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. *Journal of Strength and Conditioning Research*. 2008;22(1):153-158.

Figure 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 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

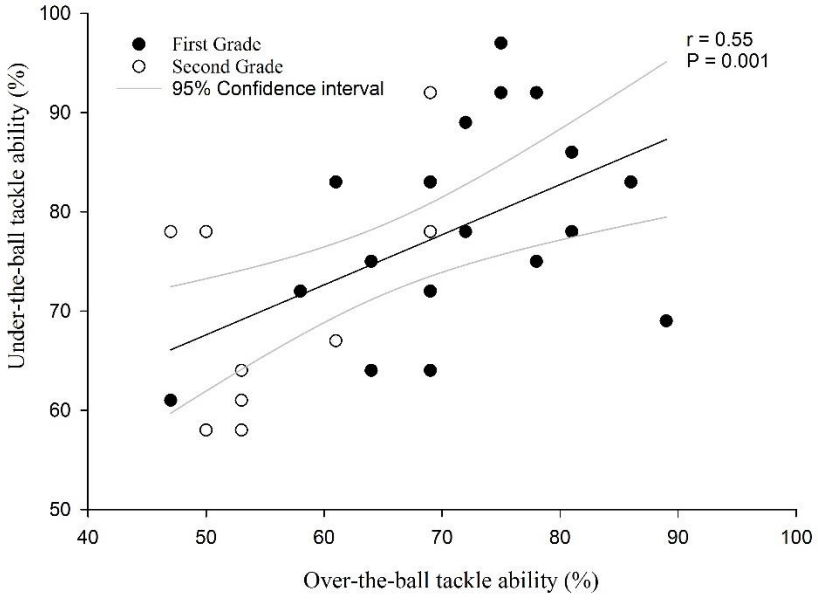

Figure 2: Over-the-ball vs under-the-ball tackle abilities.

Table 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 ($kg \cdot kg^{-1}$)	1.57 ± 0.25	1.68 ± 0.16	-0.57 (-1.23-0.28)
Relative Bench ($kg \cdot kg^{-1}$)	1.31 ± 0.17	1.39 ± 0.16	-0.45 (-1.21-0.28)
Chin-up ($kg \cdot kg^{-1}$)	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 ($W \cdot kg^{-1}$)	55.02 ± 5.19	54.13 ± 4.29	0.19 (-0.53-0.94)
PPU Peak Power ($W \cdot kg^{-1}$)	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 $P < 0.01$.

Table 2: Standardized 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)
Minimize 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 3: Relationship between tackling abilities and physiological characteristics.

	Under-the-ball tackling ability	Over-the-ball tackling 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 ($kg \cdot kg^{-1}$)	0.05	-0.26
	(-0.31-0.40)	(-0.56-0.10)
Relative Bench ($kg \cdot kg^{-1}$)	-0.20	-0.26
	(-0.52-0.17)	(-0.56-0.10)
Chin-up ($kg \cdot kg^{-1}$)	-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 ($W \cdot kg^{-1}$)	-0.18	-0.17
	(-0.50-0.19)	(-0.49-0.20)
PPU Peak Power ($W \cdot kg^{-1}$)	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 $P < 0.01$.