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Citation:

den Hollander, S and Lambert, M and Jones, B and Hendricks, S (2022) The relationship between physical qualities and contact technique in academy rugby union players. *International Journal of Sports Science and Coaching*. p. 174795412210762. ISSN 1747-9541 DOI: <https://doi.org/10.1177/17479541221076297>

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**The relationship between physical qualities and contact technique in
academy rugby union players**

Abstract

This study investigated the relationship between physical qualities and contact technique proficiency in rugby union players. Thirty-eight (n=38) male academy rugby union players participated in the study. Physical measures of anthropometry, functional mobility, strength endurance, strength, power, speed, agility, and anaerobic and aerobic endurance were assessed. Tackler, ball-carrier, and ruck technique were assessed using video analysis of a standardized two-on-two contact drill. Seven physical qualities were moderately associated with *tackler technique*; *Push-ups* ($r^2=0.2$; $\beta=0.04$; $p=0.005$; $ES=0.26$), *Sit-ups* ($r^2=0.2$; $\beta=0.08$; $p=0.004$; $ES=0.27$), *Relative 1RM Bench Press* ($r^2=0.2$; $\beta=2.32$; $p=0.003$; $ES=0.29$), *Broad Jump* ($r^2=0.2$; $\beta=0.03$; $p=0.009$; $ES=0.22$), *Agility* ($r^2=0.2$; $\beta=-0.47$; $p=0.019$; $ES=0.19$), *40m-Speed with Ball* ($r^2=0.1$; $\beta=0.93$; $p=0.027$; $ES=0.16$) and *Functional Mobility* ($r^2=0.2$; $\beta=0.16$; $p=0.007$; $ES=0.25$). There was a large association between *ball-carrier technique* and *Medicine Ball Throw* ($r^2=0.3$; $\beta=1.13$; $p=0.001$; $ES=0.37$), and a moderate association between *ruck technique* and *agility* without ($r^2=0.2$; $\beta=-0.75$; $p=0.005$; $ES=0.21$) and with ($r^2=0.2$; $\beta=-0.55$; $p=0.015$; $ES=0.29$) the ball. The findings demonstrate the important contribution of physical strength and conditioning to contact technique in rugby union players. Contact technique training should be accompanied with physical strength and conditioning, as improvements in physical qualities may serve as foundational components to underpin improvements in technique.

Key words: tackle, ruck, ball-carrier, strength & conditioning, skill

Introduction

Rugby union is collision-based sport, played in over 124 countries, with an estimated 9.6 million players worldwide.¹ During a rugby union match, opposing players physically and technically engage each other to contest for ball possession and territory, and prevent the opposing team from scoring points. The most frequently occurring of these physical-technical contests are the tackle and ruck. For example, at the community level, 141 tackles and 115 rucks occur during a match, respectively.² Winning each tackle and ruck contest is important for team success.³ At the same time, the nature of these frequent contests expose players to high risk of injury, with tackle and ruck related injury incidences of 8.4 and 1.6 injuries per 1000 playing hours at community level, respectively.² As a result, preventing injuries during the tackle and ruck, without negatively impacting players' performance in these contact events, is a high priority for all rugby stakeholders.

The physical demands of the tackle are well-recognized, and it is understood that a player requires both a high level of technical skill and physical conditioning to repeatedly engage in the tackle safely and effectively.⁴ From video analysis studies of matches, players who display a high technical proficiency during the tackle (as a ball-carrier or tackler) and ruck (clearing) have a higher likelihood of winning the contest and remaining injury-free.⁵⁻⁹ In these studies, the exact techniques which attribute to a players' high technical proficiency during an injury-free and a successful tackle or ruck have been identified.⁹⁻¹² For instance, tacklers have a lower propensity for head injuries when they hold their backs straight with their centre of gravity ahead of their base support, place their head on the correct side of the ball-carrier and face their head up and forward, while using their arms after contact.^{9 10 13} Knowing which techniques to focus on during training helps coaches optimise their contact training sessions and informs governing bodies' injury prevention strategies. The drive to improve players' contact

technique, however, have largely been focused on developing and refining players' technical-skill abilities.^{7 14}

A player's physical qualities may also act as the foundation for a player to be technically proficient. In rugby league for example, Speranza et al. showed that tackling ability was strongly correlated with lower body strength (3 repetition maximum squat and relative squat), upper body strength (3 repetition maximum bench press), and upper-body power (plyometric push-up).¹⁵ Similar findings have been reported at different playing levels in rugby league, from junior elite to professional.¹⁶⁻¹⁸ This has practical applications because strength and conditioning trainers can better prepare players for training and competition if they understand the physical qualities players require to proficiently execute contact techniques. This also enables coaches to be more specific when designing contact training sessions, that can be both technically and physically challenging (for example, performing a strength or power exercise while training certain techniques), and assist clinicians with a more focused return to play strategy after injury.⁷ All of which, will minimise the risk of injury and maximise the potential to optimally perform during the tackle and ruck. While the physical qualities associated with tackle proficiency are well described in rugby league, the same cannot be said for rugby union. Therefore, the aim of this study was to determine which physical qualities are associated with ball-carrier, tackler, and ruck techniques in rugby union.

Methods

A cross-sectional study design was used to compare the physical qualities and proficiencies of academy level rugby players during a tackle (both ball carrier and tackler) and a ruck. Thirty-eight under 20 male amateur rugby union players (n=38; 18 forwards and 20 backline players) participated in the study. All players were free from injury and had played rugby for at least

one calendar year. All procedures were approved by the designated university's human research ethics committee (HREC 778/2017).

The testing battery was conducted at the start of the preseason over two days. On day one measures of anthropometry, muscular power, functional mobility, speed, agility, and anaerobic endurance were assessed. On day two, muscular strength endurance, muscular strength, aerobic endurance, and contact technique proficiency were assessed. Before testing players were warmed up and were familiarized with the testing procedures. Players were given adequate time to recover between testing components. A full description of the testing protocol can be found in Appendix 1. The testing battery included the following:

Players' height (cm), mass (kg) and the sum of seven skinfolds (mm) were measured. The seven skinfold sites measured were triceps, biceps, subscapular, suprailiac, abdominal, thigh and calf, according to the guidelines set out by the International Society for the Advancement of Kinanthropometry.¹⁹ Functional mobility was assessed using 10 movement tests. Each test was scored on an ordinal scale from 0 to 2, where "2" described the correct performance of the movement, "1" indicated that the player required compensatory movements to perform the test, and "0" when the player was unable to perform the movement at all. A total score out of 20 was then calculated from the 10 movement tests.

Upper body muscular strength was determined by the one repetition max (1RM) bench press. The maximal weight (kg) a player was able to lift in one repetition was divided by their body mass to determine the players relative 1RM bench press (expressed %). Muscular endurance was determined using three tests - a maximal pull-up test (pronated grip), a one-minute push-up test, and a two-minute sit-up test. A vertical jump test and broad jump test were used to

assess the players' lower body power. A seated medicine ball throw test was used to assess upper body power. The Illinois agility test, modified from ²⁰ was used to assess the player's agility. For this study, agility refers to a whole-body movement with change of velocity or direction.²¹ Players performed the agility test while carrying the ball and without carrying the ball. Running speed was assessed from 0-10 m and 0-40 m using timing gates (recorded as m.s⁻¹). The players performed the sprints while carrying the ball and without carrying the ball. Momentum (kg.m.s⁻¹) at 10 m and 40 m (with and without the ball) were determined by multiplying the players' mass (kg) with their speed at 10 m and 40 m (m.s⁻¹), respectively.²² A repeat sprint shuttle test was used to assess the players anaerobic endurance, and the BRONCO test was used to assess the players aerobic endurance.²³

A two-on-two contact training drill was used to assess the tackle, ball-carry and ruck technique proficiency of the players.⁵ The drill was performed in the corner of a rugby field and filmed. The players' tackle, ball-carry and ruck technique proficiency were assessed retrospectively using standardized tackle, ball-carry and ruck technical criteria.^{5 6 10} Players were awarded 1 point for each criterion they performed and 0 points if they failed to perform the criterion. The number of criteria performed were totalled to provide a score (arbitrary units) for each tackle, ball-carry and ruck. The standardised contact drill and method of scoring players' technique has shown encouraging construct validity by differentiating between levels of play^{5 15 16} and associated with better tackle performance outcomes (for example, higher proportion of dominant tackles) in matches.²⁴⁻²⁶ Each player performed four tackles, four ball-carries and four rucks, and the total scores were averaged to calculate the tackle, ball-carry and ruck technique proficiency scores for each player.

A Shapiro-Wilk test was used to test the normality of the data. As the data were normally distributed, a linear regression analysis was done to assess the relationship between each physical quality and tackle, ball-carry and ruck technique proficiency. The physical qualities were treated as the independent variables and the contact technique proficiency scores as the dependent variable. The *a priori* level of significance was set at $p \leq 0.05$. When a significant relationship was found between a physical quality and the total technical proficiency score, a second linear regression analysis was performed between the said physical quality and each individual contact technique. Regression (r^2) and beta (β) coefficients (and 95% confidence intervals) are reported, with the β coefficient sign indicating the direction of the relationship (a positive value (>0) indicating a positive relationship and a negative value (<0) indicating a negative relationship). Cohen's F^2 effect size (ES) was used to determine the magnitude of the relationship between the variables, where $F^2 = r^2/(1 - r^2)$.²⁷ Effect sizes of <0.02 , $0.02-0.14$, $0.15-0.34$ and >0.34 were considered trivial, small, moderate and large, respectively. Only associations that were significant with moderate or large effect sizes are reported in the results text. All statistical analyses were conducted using STATA 13 (StataCorp, College Station, TX USA), and reported as means and 95% confidence intervals (95%CI).

Results

Relationship between physical qualities and the total technical proficiency score for tackle, ball-carry and ruck

Table 1 shows an overview of the relationships between physical qualities and contact technique. *Push-ups* ($r^2=0.2$; $\beta=0.04$, 95%CI 0.01-0.06), *Sit-ups* ($r^2=0.2$; $\beta=0.08$, 95%CI 0.03-0.14), *Relative 1RM Bench Press* ($r^2=0.2$; $\beta=2.32$, 95%CI 0.83-3.80), *Broad Jump* ($r^2=0.2$; $\beta=0.03$, 95%CI 0.01-0.04), *Agility* ($r^2=0.2$; $\beta=-0.47$, 95%CI -0.86--0.08), *40m-Speed with Ball* ($r^2=0.1$; $\beta=0.93$, 95%CI 0.11-1.74) and *Functional Mobility* ($r^2=0.2$; $\beta=0.16$) had a moderate

association with *tackler technique*. *Medicine Ball Throw* had a large association on *ball-carrier technique* ($r^2=0.3$; $\beta=1.13$, 95%CI 0.50-1.76). *Height* ($r^2=0.3$; $\beta=-0.07$, 95%CI -0.12--0.03), *Agility* ($r^2=0.2$; $\beta=-0.75$, 95%CI -1.25--0.25) and *Agility with Ball* ($r^2=0.2$; $\beta=-0.55$, 95%CI -0.99--0.12) had a moderate association with *ruck technique*.

Relationship between specific physical qualities and tackler techniques

Agility was moderately associated with three tackler techniques; *Contacting the ball-carrier with the shoulder as the first point of contact* ($r^2=0.2$; $\beta=-0.11$, 95%CI -0.19--0.03), *Contacting the ball-carrier in the centre of gravity* ($r^2=0.2$; $\beta=-0.16$, 95%CI -0.26--0.06), and *Using the shoulder to impede or disrupt the ball-carrier* ($r^2=0.1$; $\beta=-0.08$, 95%CI -0.15--0.01) (Table 2). Similarly, *40m-Speed* had a large association with *Contacting the ball-carrier with the shoulder as the first point of contact* ($r^2=0.3$; $\beta=0.30$, 95%CI 0.13-0.46) and a moderate association with *Using the shoulder to impede or disrupt the ball-carrier* ($r^2=0.2$; $\beta=0.19$, 95%CI 0.04-0.33). *40m-Speed* also had a moderate association with *Repositioning from an upright to crouched body position* ($r^2=0.2$; $\beta=0.12$, 95%CI 0.02-0.22).

Muscular strength and endurance assessments, and the lower body power assessment *broad jump*, were moderately associated with tackler techniques (Table 3). *Push-ups* had a moderate association with *Bending elbows with hands raised above the level of the elbow and elbows close to torso* ($r^2=0.1$; $\beta=0.008$, 95%CI 0.001-0.014) and *Contacting the ball-carrier with the shoulder as the first point of contact* ($r^2=0.2$; $\beta=0.008$, 95%CI 0.003-0.012). *Contacting the ball-carrier with the shoulder as the first point of contact* was also moderately associated with *Pull-ups* ($r^2=0.1$; $\beta=0.02$, 95%CI 0.002-0.03) and *Relative 1RM Bench Press* ($r^2=0.2$; $\beta=0.44$, 95%CI 0.15-0.73). In addition, *Relative 1RM Bench Press* was moderately associated with *Releasing the ball-carrier and joining the defensive line* ($r^2=0.1$; $\beta=0.45$, 95%CI 0.15-0.84). *Sit-*

ups was moderately associated with *approaching the ball-carrier from the front/oblique* ($r^2=0.2$; $\beta=-0.004$, 95%CI -0.007--0.001), while *Broad jump* had a moderate association with the post contact technique *Using shoulder to impede and disrupt the ball-carrier* ($r^2=0.2$; $\beta=0.005$, 95%CI 0.002-0.008).

Relationship between specific physical qualities and ball-carrier techniques

Medicine Ball Throw had a moderate association with the post contact ball-carrier techniques *Using of arms and/or shoulder to push tackler* ($r^2=0.1$; $\beta=0.16$, 95%CI 0.03-0.29) and *Going to ground and presenting ball* ($r^2=0.3$; $\beta=0.13$, 95%CI 0.05-0.20). The relationships between upper body-power and ball-carry techniques is shown in Table 4.

Relationship between specific physical qualities and ruck techniques

Height had a moderate association with the pre-contact ruck technique *Identifying the target* ($r^2=0.2$; $\beta=-0.02$, 95%CI -0.03--0.01). The *Illinois* agility test was moderately associated with the ruck contact technique *Head placement on the correct side of opponent* ($r^2=0.2$; $\beta=-0.11$, 95%CI-0.19--0.02). *Illinois with Ball* had a similar association with *Head placement on correct side of opponent* ($r^2=0.2$; $\beta=-0.11$, 95%CI -0.18--0.04), and *Head up and forward* ($r^2=0.1$; $\beta=-0.12$, 95%CI -0.12-0.09). Table 5 shows the relationships between height, agility, and agility with the ball on ruck technique.

Tables 1-5 near here

Discussion

This is the first study to associate rugby union player's physical qualities with tackler, ball-carrier, and ruck techniques performed during a standardised contact drill. In rugby league, higher technical proficiency scores on the standardised tackle drill has been associated with

better tackle performance outcomes (for example, higher proportion of dominant tackles) in matches.²⁴⁻²⁶ Muscular strength and endurance, upper body strength, lower body muscle power, mobility, agility and 40m-Speed (with the ball) were associated with tackling, while only upper body power and agility (with and without the ball) were associated with carrying the ball into contact and rucking, respectively. The physical qualities associated with each contact skill is indicative of the physical-technical demands to optimally perform each skill.²⁸ In rugby league, the physical qualities that correlate with tackling ability seems to differ by playing level. For example, in junior elite and professional rugby league, acceleration (10m-sprint) and lower body muscle power (vertical jump) has been associated with tackling ability. In contrast, lower body strength (3 repetition maximum squat and relative squat), upper body strength (3 repetition maximum bench press), and upper-body power (plyometric push-up) has been associated with tackling ability in semi-professional rugby league. While there are noteworthy methodological differences (for example, technical criteria) between the present study and previous work in rugby league, the collective findings in rugby league suggest that association between physical qualities and technical ability may also differ by playing level in rugby union. Further work in this area is however required to support or refute this hypothesis.

The association between certain physical qualities and specific techniques not only discloses the physical-technical demand of tackling, but also how these physical attributes may play a role in optimising tackling performance. The skill of tackling, asks players to stop/impede a physical body (of different masses), often moving in the opposite direction. To complete this task safely and effectively, tacklers need to assume specific body positions in preparation for contact, during contact, and after contact - and tacklers are expected to perform these movements 10-15 times during a match (depending on playing position).²⁹ Considering the associations between sprint speed and agility with specific pre-contact and contact techniques

(Table 2), having enough time to move into these specific body positions may be a key factor. In other words, faster players can get to the contact point quicker, which allows them more time to prepare for contact. In rugby league, acceleration (10m-sprint) has been correlated with tackling ability.^{16 17} In the present study, 40m-speed with the ball was moderately associated with tackling, and not 10m-speed (with and without the ball). The lack of 10m-speed association in the current study compared to the studies in rugby league may be explained by the difference in tackle dynamics created by the standardised tackle drills. Our tackle drill included a ruck after the tackle, a contest for the ball on the ground which does not exist in rugby league. For this reason, players in the rugby league studies may have been accelerating fully into the tackle. In rugby union, moderate approach speeds have been recommended to execute an effective tackle, and win the ensuing ruck.^{30 31} The association between 40m-speed with the ball and tackling is difficult to explain. Sprinting with the ball over 40m requires superior running balance and control, therefore speculatively, the association with tackling may be a proxy of players ability to balance and control their running.^{32 33}

Sprinting speed and agility, along with upper body muscular endurance and upper muscular strength, were also associated with contacting the ball-carrier with the shoulder as the first point of contact. Video analysis studies of tackling technique in matches has shown that the inability of tacklers to contact the ball-carrier with the shoulder as the first point of contact significantly increases players injury risk, and reduces the likelihood of a positive tackle outcome.^{6 11 30} This tackling technique is also encouraged in coaching manuals of national injury prevention programmes.^{34 35 36} Contacting the ball-carrier with the shoulder as the first point of contact is an important technique since it is the moment of first contact between the ball-carrier and tackler.¹¹ Because it is the moment the tackler and ball-carrier physically engages, tacklers experience a peak in physical load.³⁷ Therefore, plausibly, contacting the ball-carrier with the

shoulder as the first point of contact is the most physically demanding tackling technique and may explain why it was associated with four physical qualities.

Upper body power was associated to two post contact ball-carrier techniques - using the arm/or shoulder to push the tackler, and going to ground and presenting the ball. Video analysis studies of matches has shown that ball-carriers that use their arm/shoulder to push the tackler away after contact have a higher probability of offloading the ball and breaking the tackle.^{8,38} It also reduces ball-carrier's risk of injured getting injured in the tackle.^{9,39} Using the arm/shoulder to push the tackler away after contact requires a rapid, forceful action, and the association of this technique with upper body power highlights the specific physical demands to optimally perform this technique. Having high levels of upper body power also gives the ball-carrier the ability to actively wrestle the tackler in order to go to ground and present the ball, which significantly increases the likelihood of maintaining ball possession at the ruck.^{8,38}

Agility, the ability to change direction quickly and accelerate-decelerate efficiently,²¹ was associated with correct head placement before (head up, face forward) and during contact (correct side of opponent). There is a level of uncertainty to when a ruck may occur, as it only occurs when the tackler is successful in bringing the ball-carrier down. As such, a supporting players' running line may be to receive an offload or pass from the ball-carrier. When the ball-carrier is brought to ground, the supporting players' running line needs to change and the player must prepare for the ruck contest. This is where the superior ability to change direction quickly and accelerate-decelerate efficiently may come into effect.

The associations between the physical qualities identified in this study and tackler, ball-carrier and ruck techniques provide strength and conditioning trainers, clinicians, and coaches with

insight into the specific physical requirements to optimally contest in the tackle and ruck. Strength and conditioning trainers may be able to use these results to design contact specific physical training programmes to enhance training adaptation; clinicians can monitor these physical qualities to return players back to contact safely after an injury; and coaches can use the information presented here to set the optimum physical-technical challenge during contact training sessions.⁷ These improved clinical and coaching practices will have a positive impact on tackle and ruck injury prevention and management efforts, and will also improve player performance.

A few considerations and limitations need to be noted. The human body is a complex system. While the identified physical qualities associated with contact techniques offers practitioners a focus to optimize physical training and preparation for the tackle and ruck, the physical qualities not associated with tackle and ruck techniques still have a role to play in the overall physical conditioning of the player. Also, this study used a cross-sectional study design, and data from rugby league suggests that a player's physical qualities and tackling technique may change throughout the season.⁴⁰ Future work should use randomised-control type study designs to determine the effect of changes in physical qualities (such as strength, power and agility) on tackler, ball-carrier, and ruck techniques. Physical fatigue can potentially affect players' tackling technique.⁴¹ In the current study, players completed the tackle and ruck technique assessment in a non-fatigued state. Thus, it would be interesting and useful to test whether the relationship between the player's physical qualities and contact technique changes as the player completes the tackle and ruck technique assessment in increasingly fatiguing states. Lastly, the current study analysed the data using univariate statistics, and assumed that the variables are independent of each other. This approach was used to identify which physical qualities are associated with specific contact techniques. While this approach satisfied the objectives of this

study, more sophisticated approaches (for example, partial least squares correlation analysis) have been proposed to overcome the limitations of univariate statistics, and should be considered in future studies of this nature.⁴²

Conclusion

In conclusion, muscular strength, upper body strength, lower body muscle power, agility and mobility were associated with tackling during the standardised contact drill, while only upper body power and agility (with and without the ball) were associated with carrying the ball into contact and rucking, respectively. The physical qualities associated with each contact skill performed in the contact drill is indicative of the physical-technical demands to optimally perform each skill. The associations between the physical qualities identified in this study and tackler, ball-carrier and ruck techniques, provide strength and conditioning trainers, clinicians, and coaches insight into the specific physical requirements to optimally contest the tackle and ruck.

Declaration of Interest

The authors have no declarations of interest to disclose.

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Table 1 The association between physical qualities and overall tackle, ball-carry and ruck technique proficiency (data includes means, 95% confidence intervals (95% CI), and effect sizes (ES) with interpretations).

Category	Physiological Measures	Mean	95% CI	on Tackle Technique		on Ball-carry Technique		on Ruck Technique	
				ES	Interpretation	ES	Interpretation	ES	Interpretation
Anthropometry	Height (cm)	176.2	172.9-179.6	0.06	Small	0.00	Trivial	0.34	Moderate**
	Weight (kg)	88.3	82.2-94.4	0.03	Small	0.05	Small	0.14	Small*
	Sum of 7 Skinfolts (cm)	100.1	83.9-116.4	0.05	Small	0.00	Trivial	0.03	Small
Strength Endurance	Push-ups (n)	43	38-48	0.26	Moderate**	0.03	Small	0.03	Small
	Sit-ups (n)	38	35-40	0.27	Moderate**	0.04	Small	0.00	Trivial
	Pull-ups (n)	8	6-10	0.12	Small	0.00	Trivial	0.03	Small
Strength	Relative 1RM Bench Press (kg.kg ⁻¹)	1.1	1.0-1.2	0.29	Moderate**	0.04	Small	0.03	Small
Power	Relative Vertical Jump (cm)	48.7	46.0-51.4	0.15	Small*	0.01	Trivial	0.00	Trivial
	Broad Jump (cm)	55.0	52.3-57.3	0.22	Moderate**	0.05	Small	0.00	Trivial
	Medicine Ball Throw (cm)	549.6	525.9-573.3	0.07	Small	0.37	Large**	0.04	Small
Agility	Agility (s)	16.6	16.3-17.0	0.19	Moderate*	0.00	Trivial	0.29	Moderate**
	Agility with ball (s)	16.9	16.5-17.3	0.06	Small	0.00	Trivial	0.21	Moderate*
Speed	10m-Speed (m.s ⁻¹)	5.7	5.6-5.7	0.03	Small	0.05	Small	0.02	Trivial
	40m-Speed (m.s ⁻¹)	7.2	7.0-7.3	0.11	Small	0.02	Small	0.07	Small
	10m-Speed with ball (m.s ⁻¹)	5.6	5.5-5.7	0.12	Small	0.06	Small	0.00	Trivial
	40m-Speed with ball (m.s ⁻¹)	7.2	7.0-7.3	0.16	Moderate*	0.03	Small	0.04	Small
Momentum	Momentum - 10m (kg. m.s ⁻¹)	496.0	463.7-528.3	0.02	Small	0.11	Small	0.13	Small*
	Momentum - 40m (kg. m.s ⁻¹)	629.5	591.2-667.8	0.01	Trivial	0.11	Small	0.11	Small
Endurance	Repeat Sprint (m)	600	570-630	0.03	Small	0.00	Trivial	0.08	Small
	BRONCO (min:s)	5:44	5:34-5:55	0.02	Small	0.00	Trivial	0.05	Small
Mobility	Functional Mobility (AU)	8.5	8.0-9.0	0.25	Moderate**	0.02	Small	0.00	Trivial

* p <0.05

** p <0.01

Table 2 The association between agility, 40m-speed and functional mobility and each tackler technique (includes means, 95% confidence intervals (95% CI), and effect sizes (ES) with interpretations).

Tackle Technique Proficiency	Mean	95% CI	Agility		40m-Speed		Functional Mobility	
			ES	Interpretation	ES	Interpretation	ES	Interpretation
<i>Pre-contact</i>								
Identify ball-carrier and position to ensure shoulder contact is made	0.9	0.9-1.0	0.01	Trivial	0.03	Small	0.00	Trivial
Reposition from an upright to crouched/bent at the waist body position	0.9	0.9-1.0	0.13	Small	0.19	Moderate*	0.01	Trivial
Keep backs straight with centre of gravity forward of the support base	0.2	0.1-0.3	0.00	Trivial	0.00	Trivial	0.11	Small
Alignment square to ball-carrier (hips aligned)	0.9	0.8-0.9	0.00	Trivial	0.00	Trivial	0.00	Trivial
Head up and face forward	0.7	0.6-0.7	0.08	Small	0.03	Small	0.04	Small
Bend elbows with hands raised above the level of the elbow and elbows close to torso	0.2	0.1-0.3	0.01	Trivial	0.00	Trivial	0.06	Small
Exhibit shorter and faster steps when approaching ball-carrier (feet remain active)	0.3	0.2-0.4	0.02	Small	0.05	Small	0.02	Small
Approach from front/oblique	1.0	1.0-1.0	0.05	Small	0.00	Trivial	0.00	Trivial
<i>Contact</i>								
Explosiveness (rapid leg movement) on contact	0.1	0.1-0.2	0.01	Trivial	0.01	Trivial	0.00	Trivial
Contact the ball-carrier with the shoulder as the first point of contact	0.7	0.7-0.8	0.27	Moderate**	0.41	Large**	0.03	Small
Contact ball-carrier in centre of gravity (upper pelvis/lower torso)	0.6	0.5-0.7	0.32	Moderate**	0.13	Small*	0.02	Small
Place head beside or behind ball-carrier's body correctly	0.8	0.7-0.9	0.00	Trivial	0.01	Trivial	0.13	Small*
<i>Post contact</i>								
Use shoulder to impede or disrupt the ball-carrier	0.2	0.1-0.3	0.16	Moderate*	0.21	Moderate*	0.13	Small*
Leg drive upon contact	0.1	0.1-0.2	0.14	Small*	0.05	Small	0.07	Small
Wraps arms around ball-carrier and maintains hold	0.6	0.6-0.7	0.00	Trivial	0.02	Small	0.01	Trivial
Release ball-carrier and join the defensive line	0.7	0.6-0.8	0.09	Small	0.05	Small	0.11	Small
Total	8.86	8.5-9.3	0.19	Moderate*	0.16	Moderate*	0.25	Moderate**

* p <0.05

** p <0.01

Table 3 The association between muscular strength and lower-body power and each tackler technique (includes means, 95% confidence intervals (95% CI), and effect sizes (ES) with interpretations).

Tackle Technique Proficiency			Push-ups		Sit-ups		Pull-ups		Relative 1RM Bench-press		Broad Jump	
	Mean	95% CI	ES	Interpretation	ES	Interpretation	ES	Interpretation	ES	Interpretation	ES	Interpretation
Pre-contact												
Identify ball-carrier and position to ensure shoulder contact is made	0.9	0.9-1.0	0.01	Trivial	0.00	Trivial	0.05	Small	0.01	Trivial	0.00	Trivial
Reposition from an upright to crouched/bent at the waist body position	0.9	0.9-1.0	0.03	Small	0.15	Small*	0.14	Small*	0.05	Small	0.12	Small*
Keep backs straight with centre of gravity forward of the support base	0.2	0.1-0.3	0.02	Small	0.08	Small	0.06	Small	0.07	Small	0.12	Small
Alignment square to ball-carrier (hips aligned)	0.9	0.8-0.9	0.00	Trivial	0.03	Small	0.03	Small	0.01	Trivial	0.02	Small
Head up and face forward	0.7	0.6-0.7	0.01	Trivial	0.00	Trivial	0.01	Trivial	0.00	Trivial	0.00	Trivial
Bend elbows with hands raised above the level of the elbow and elbows close to torso	0.2	0.1-0.3	0.16	Moderate*	0.12	Small*	0.01	Trivial	0.06	Small	0.03	Small
Exhibit shorter and faster steps when approaching ball-carrier (feet remain active)	0.3	0.2-0.4	0.00	Trivial	0.01	Trivial	0.06	Small	0.00	Trivial	0.01	Trivial
Approach from front/oblique	1.0	1.0-1.0	0.07	Small	0.18	Moderate*	0.11	Small	0.05	Small	0.03	Small
Contact												
Explosiveness (rapid leg movement) on contact	0.1	0.1-0.2	0.00	Trivial	0.02	Small	0.00	Trivial	0.01	Trivial	0.00	Trivial
Contact the ball-carrier with the shoulder as the first point of contact	0.7	0.7-0.8	0.32	Moderate**	0.05	Small	0.16	Moderate*	0.27	Moderate**	0.09	Small
Contact ball-carrier in centre of gravity (upper pelvis/lower torso)	0.6	0.5-0.7	0.09	Small	0.03	Small	0.04	Small	0.11	Small	0.13	Small*
Place head beside or behind ball-carrier's body correctly	0.8	0.7-0.9	0.11	Small	0.01	Trivial	0.08	Small	0.10	Small	0.05	Small
Post contact												
Use shoulder to impede and disrupt the ball-carrier	0.2	0.1-0.3	0.08	Small	0.09	Small	0.09	Small	0.06	Small	0.27	Moderate**
Leg drive upon contact	0.1	0.1-0.2	0.01	Trivial	0.01	Trivial	0.00	Trivial	0.00	Trivial	0.04	Small
Wraps arms around ball-carrier and maintains hold	0.6	0.6-0.7	0.01	Trivial	0.00	Trivial	0.00	Trivial	0.00	Trivial	0.00	Trivial
Release ball-carrier and join the defensive line	0.7	0.6-0.8	0.12	Small*	0.07	Small	0.07	Small	0.16	Moderate*	0.06	Small
	8.86	8.5-9.3										

* p <0.05

** p<0.01

Table 4 The association between medicine ball throw and each ball-carrier technique (includes means, 95% confidence intervals (95% CI), and effect sizes (ES) with interpretations).

Ball-carry Technique Proficiency	Mean	95% CI	Medicine Ball Throw	
			ES	Interpretation
<i>Pre-contact</i>				
Focus on tackler	1.0	1.0-1.0	0.00	Trivial
Body position - upright to low (dipping)	0.8	-.8-0.9	0.01	Trivial
Back straight, centre of gravity ahead of support base	0.6	0.5-0.6	0.02	Small
Shift ball away from contact to correct arm	0.7	0.5-0.8	0.03	Small
Head up, face forward	0.9	0.8-1.0	0.02	Small
Shuffle or evasive manoeuvre	0.4	0.2-0.5	0.01	Trivial
<i>Contact</i>				
Fend into contact	0.2	0.1-0.3	0.06	Small
Side-on into contact	0.5	0.4-0.6	0.10	Small
Explosiveness on contact	0.7	0.5-0.8	0.09	Small
Body position – from low up into contact	0.5	0.4-0.6	0.02	Small
Ball in correct arm and protected	0.7	0.6-0.8	0.02	Small
<i>Post contact</i>				
Use of arm and/or shoulder to push tackler	0.3	0.2-0.4	0.17	Moderate*
Leg drive upon contact	0.7	0.6-0.8	0.11	Small
Go to ground and present ball	0.9	0.8-1.0	0.34	Moderate**
<i>Total</i>	8.8	8.3-9.3	0.37	Large**

* p <0.05

** p<0.01

Table 5 The association between height, agility and agility with ball on each ruck technique (includes means, 95% confidence intervals (95% CI), and effect sizes (ES) with interpretations).

Ruck Technique Proficiency	Mean	95% CI	Height		Agility		Agility with Ball	
			ES	Interpretation	ES	Interpretation	ES	Interpretation
<i>Pre-contact</i>								
Identify target	0.8	0.7-0.9	0.31	Moderate**	0.13	Small*	0.06	Small
Body position - upright to low (dipping)	1.0	0.9-1.0	0.00	Trivial	0.00	Trivial	0.00	Trivial
Back straight, centre of gravity ahead of support base	0.5	0.3-0.6	0.15	Small*	0.10	Small	0.11	Small
Enter from behind/alongside last man's feet	1.0	1.0-1.0	0.03	Small	0.01	Trivial	0.01	Trivial
Head up, face forward	0.5	0.3-0.6	0.08	Small	0.08	Small	0.16	Moderate*
Boxer stance – elbows low and close, hands up	0.2	0.1-0.3	0.06	Small	0.01	Trivial	0.00	Trivial
Shortening steps	0.4	0.3-0.5	0.14	Small*	0.11	Small	0.02	Trivial
Head and shoulders above hips	0.5	0.4-0.6	0.07	Small	0.03	Small	0.03	Small
<i>Contact</i>								
Dip and step into contact	0.2	0.1-0.3	0.00	Trivial	0.06	Small	0.00	Trivial
Enter from low to high position	0.6	0.5-0.7	0.00	Trivial	0.04	Small	0.10	Small
Contact with shoulder	0.8	0.6-0.9	0.04	Small	0.01	Trivial	0.07	Small
Head placement on correct side of opponent	0.8	0.7-0.9	0.02	Small	0.21	Moderate*	0.30	Moderate**
<i>Post contact</i>								
Punch arms forward, wrap and pull (hit and stick)	0.4	0.3-0.5	0.10	Small	0.00	Trivial	0.01	Trivial
Leg drive upon contact and clean out opponent	0.4	0.3-0.5	0.02	Small	0.07	Small	0.09	Small
Stay on feet	0.6	0.5-0.7	0.02	Small	0.07	Small	0.11	Small
Total	8.5	8.0-9.0	0.34	Moderate**	0.29	Moderate**	0.21	Moderate*

* p <0.05

** p <0.01