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The speed and acceleration of the ball carrier and tackler into contact during front-on tackles in rugby league

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ABSTRACT

The aim was to use a combination of video analysis and microtechnology (10 Hz global positioning system [GPS]) to quantify and compare the speed and acceleration of ball-carriers and tacklers during the pre-contact phase (contact − 0.5s) of the tackle event during rugby league match-play. Data were collected from 44 professional male rugby league players from two Super League clubs across two competitive matches. Tackle events were coded and subject to three stages of inclusion criteria to identify front-on tackles. 10 Hz GPS data was synchronised with video to extract the speed and acceleration of the ball-carrier and tackler into each front-on tackle ($n = 214$). Linear mixed effects models (effect size [ES], confidence intervals, p-values) compared differences. Overall, ball-carriers ($4.73 \pm 1.12\ m \cdot s^{-1}$) had greater speed into front-on tackles than tacklers ($2.82 \pm 1.07\ m \cdot s^{-1}$; ES = 1.69). Ball-carriers accelerated ($0.67 \pm 1.01\ m \cdot s^{-2}$) into contact whilst tacklers decelerated ($-1.26 \pm 1.36\ m \cdot s^{-2}$; ES = 1.74). Positional comparisons showed speed was greater during back vs. back (ES = 0.66) and back vs. forward (ES = 0.40) than forward vs. forward tackle events. Findings can be used to inform strategies to improve performance and player welfare.

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Introduction

In rugby league, a tackle event is a physical-technical engagement whereby a tackler (i.e., defender) attempts to stop the ball-carrier (i.e., attacker) (Hollander et al., 2021). The tackle is the most injurious event in rugby league, common injuries include contusions, strains, sprains and fractures (Burger et al., 2021; King et al., 2012). The tackle event also poses risk of head impacts with approximately one head impact assessment (HIA) occurring every match (Gardner et al., 2021). Similarly, in rugby union, tackling and being tackled front-on are the largest risk factors for head impacts (Kemp et al., 2008). Therefore, there is a need to understand the characteristics of the tackle event from a technical (e.g., tackle direction and tackle height) and physical (e.g., speed and acceleration into contact, energy distribution between ball-carrier and tackler upon contact, finally the duration of the contact event) perspective.

Video analysis of the tackle has been used during rugby league to assess tackle technique (Hopkinson et al., 2022), tackle height (King et al., 2010) and their influence on tackle success (Speranza et al., 2018), injury (King et al., 2012), and head impacts (Gardner et al., 2021). Research assessing the technical aspects of the tackle has typically focused on controlled field sessions to identify factors affecting technique (Hollander et al., 2021). It is likely that the technical aspects of the tackle are underpinned by the physical characteristics of the tackle, which are influenced by both the ball-carrier and tackler. The physical characteristics of the tackle include the physical characteristics of the ball-carrier and tackler such as their strength and power capabilities, and the dynamic components of the tackle (i.e., speed and acceleration into the tackle) (Speranza et al., 2017). A greater ball-carrier speed may reduce the time a tackler has to adopt correct technique, and equally, a greater tackler speed may reduce the time the ball-carrier has to brace for the collision. Therefore, quantifying the speed of the ball-carrier and tackler at the point of contact is important from both a performance and injury prevention perspective.

Tackle frequencies have been commonly reported, ranging from ≈ 14 to 52 per player during a match, dependent on playing position (Rennie et al., 2022). This approach assumes all tackles lead to the same outcomes and has the same level of risk. One factor influencing the characteristics of the tackle is the speed and acceleration characteristics of the ball-carrier and tackler when entering a tackle event, with player acceleration and ball-tackler speed possessing the greatest variable importance in relation to concussion in rugby union (Cross et al., 2019). In rugby union, the speed into tackles has been

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quantified through video analysis by manually coding pitch coordinates for each 0.1 s interval, then calculating speed and acceleration using planar location (Hendricks et al., 2012). No significant differences were identified between ball-carrier and tackler speed (mean = 4.8 vs. 5.0 $m{\cdot}s^{-1}$) into contact. In simulated conditions, multibody modelling of the rugby union tackle showed that inertial head kinematics for both ball-carrier and tackler were greater with increases in speed, peaking at ball-carrier and tackler velocities of 10 $m{\cdot}s^{-1}$ (Tierney & Tucker, 2022). Similarly, in youth American Football, ~75% of the variance in head acceleration magnitude was explained by the speed leading up to the impact, with the greatest head acceleration magnitudes reported at the highest impact velocities (Campolettano et al., 2018). However, these findings may not translate to rugby league given the rule differences between sports. For example, in rugby league, defenders must retreat 10 m from the play-the ball, allowing the attacking team to advance, potentially leading to differences in running speed of both ball-carrier and tackler in the next phase of play. To date, the speed into tackles for ball-carrier and tackler has not yet been established during rugby league match play.

Current video analysis methods to calculate ball-carrier and tackler speed are time-consuming and likely influenced by the subjective nature of the analyst (Naughton et al., 2020). Combining video analysis and microtechnology could reduce the duration of time and researcher error involved with manually coding multiple frames to calculate speed. This method has been used to assess the peak speed of tackles in Australian Football, by identifying the initial point of contact using video and subsequently aligning with 10 Hz microtechnology data to find the peak speed within a 3 s window (1 s before pre and 2 s after post contact) (Gastin et al., 2013). However, assessing peak speed during a time window that ends after contact could lead to an overestimation of the speed upon entry into the tackle, as the contact event between ball-carrier and tackler may lead to an increased speed momentarily after contact. Assessing speed over a time period prior to contact allows for increased depth into the context of the tackles by assessing the derivatives of speed namely the acceleration. An understanding of these variables is particularly important for player welfare considering the relationship the acceleration profile has with the potential negative outcomes of the tackle (Cross et al., 2019).

Therefore, this study aims to combine video analysis and microtechnology to compare the speed and acceleration of the ball-carrier and tackler during the pre-contact phase of front-on tackles during Super League match play, whilst also comparing the effect of the interaction of ball-carrier and tackler position.

Methods

Study design

An observational research design was conducted in which video and microtechnology data from 214 front-on tackles from 44 male rugby league players from two Super League clubs across two competitive matches were analysed to quantify the speed and acceleration of the ball-carrier and tackler into contact. This allowed each tackle event to possess data on both the ball-carrier and tackler. Figure 1 shows the workflow of data used in the study with reference to collection, processing, and statistical analysis of data. Ethics approval (number: 91051) was granted by the Leeds Beckett University ethics committee and players provided written consent to participate in the study.

Data collection and tackle event inclusion

Tackle identification and notational analysis of tackle events were carried out by the lead researcher using broadcast footage analysed using Catapult Vision (Catapult Sports, Melbourne, Australia). The intrarater reliability for identification and inclusion of tackle events was (κ = 0.96), following a four-week washout period. For this study, a tackle was defined as the first contact made by a tackler on a ball-carrier, without reference to whether the ball-carrier went to ground or the outcome of the tackle (Quarrie & Hopkins, 2008). Each tackle was subjected to the three stages of inclusion criteria. There was an initial total of 632 tackle events across the two matches.

The initial inclusion phase focused on whether the ball-carrier and tackler could be clearly identified from the match video and whether the initial point of contact in the tackle could be clearly identified. Nine tackle events were excluded due to the ball-carrier or tackler not being clearly identified whilst 17 were excluded as the point of contact could not be clearly identified. This led to an initial total of 606 tackle events across both matches.

The second phase of inclusion ($n = 606$) was then assessed based on the pre-contact phase (0.5 s before the initial contact) (Hopkinson et al., 2022). The inclusion criteria for this phase were to ensure tackles were front-on tackles, this was done by first assessing whether the ball-carrier ran straight towards the tackler during the pre-contact phase (number of tackles excluded = 51) and did not deviate from that path through an evasive side-step, initiated by either leg, away from the tackler (number of tackles excluded $n = 121$) (Hendricks et al., 2012; Hopkinson et al., 2022). After the second phase of inclusion, this led to a total of 434 tackle events across both matches.

The third phase of inclusion was then assessed based on the initial contact and if the initial point of contact by the tackler was on an anterior body part (e.g., abdomen, quadriceps, etc.) of the ball-carrier, this phase excluded side-on tackles (number of tackles excluded $n = 166$) (Hendricks et al., 2012). This provided a total of 268 observations for subsequent analysis. An example of a tackle included in the analysis has been shown in Figure 2.

Microtechnology data were collected by the sport science support staff of both Super League teams, as is common practice and consistent with the methods outlined by Dalton-Barron et al. (2020). All data were accessed through Catapult Openfield (Version 3.4.1). Speed into the tackle for both the ball-carrier and tackler was calculated using the raw-Doppler derived speed using micro-electrical mechanical system (MEMS) devices with enabled Global Navigation Satellite System (GNSS) technology (Vector S7, Catapult Sports, Melbourne, Australia). These provide geospatial positioning at a 10 Hz sampling frequency encompassing both Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS) satellites. Microtechnology has previously been found to be a valid method with good reliability (CV = 0.1% to 3.9%) when assessing peak running velocities and average acceleration (Crang et al., 2022).

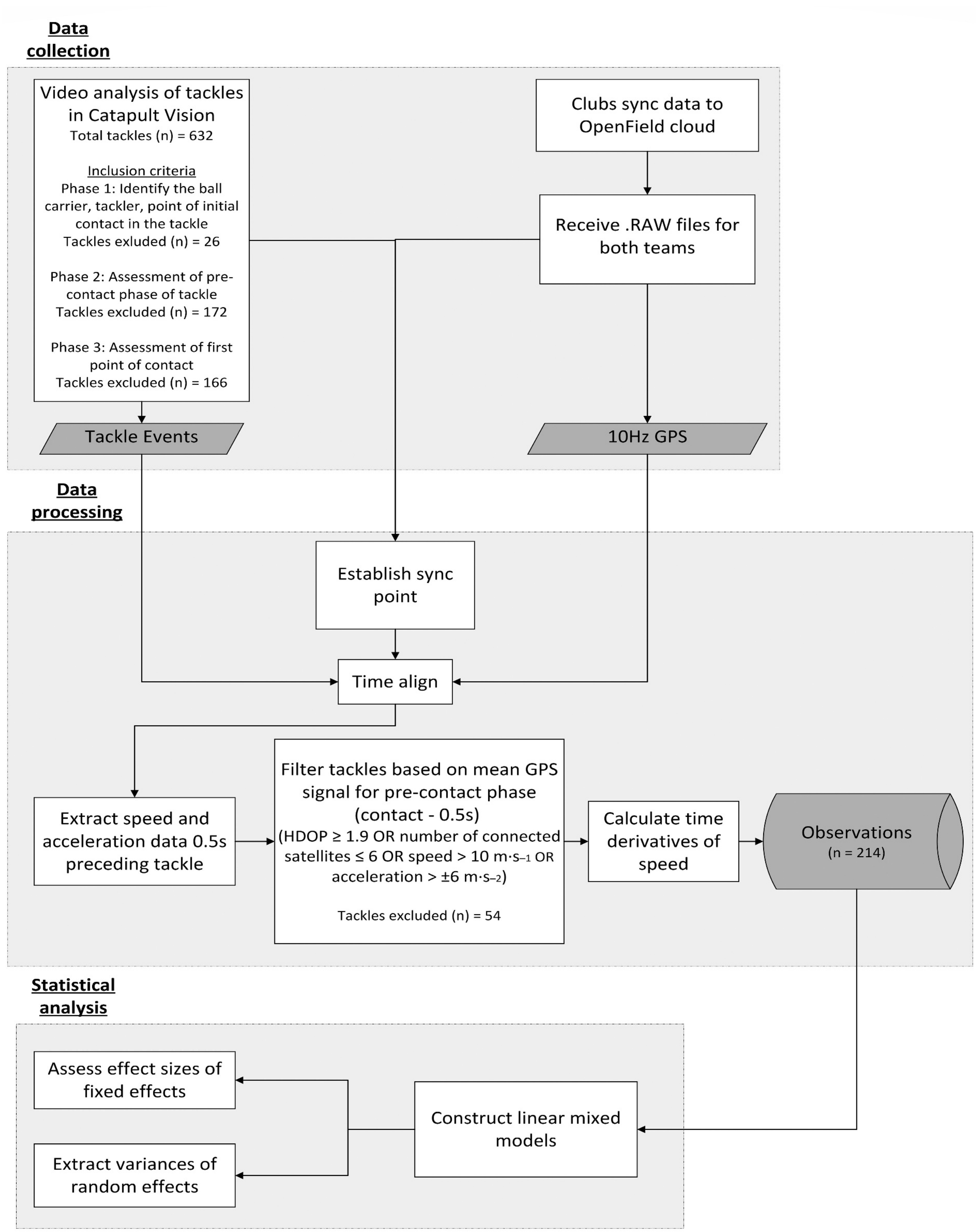

Figure 1. Workflow of procedures to obtain, time-align and analyse data for use within the study. The diagram shows three key stages of data collection, data processing and statistical analysis.

Data processing

A keyhole markup language (KML) of the match venues was imported into Catapult OpenField (Version 3.4.1) to plot the positional data of players. A sync point between the video analysis data and microtechnology data was established by comparing movement of players at kick off of each half in the video to plotted longitudinal and latitudinal positional data from the microtechnology in Catapult OpenField, a confirmatory measure of using a change in speed from a relatively static position of the player kicking off was implemented. Subsequently, this sync

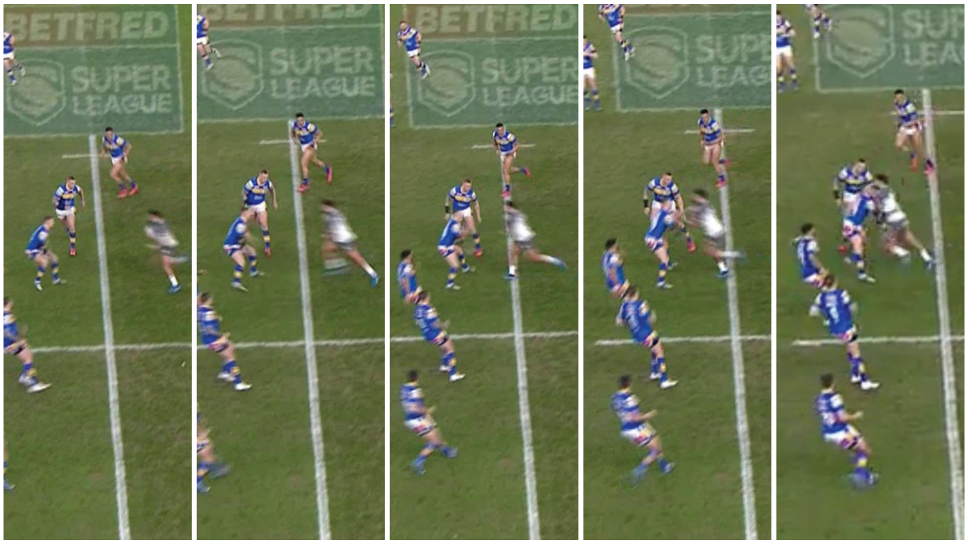

Figure 2. An example of front-on tackle included in analysis based on the inclusion criteria.

point was used to create a timestamp for all tackle data. All subsequent steps were completed in R Studio (RStudio version 2022.02.1; R Version 4.2.1). The tackle event data and microtechnology data were then aligned. Following this, the 10 Hz speed and acceleration data for 0.5 s preceding initial contact for each tackle were extracted from the 10 Hz dataset. Erroneous data were removed based on a mean for the pre-contact phase (contact − 0.5 s): number of connected satellites ≤ 6, Horizontal Dilution of Precision (HDOP) ≥1.9, speed >10 $m{\cdot}s^{-1}$ and acceleration >±6 $m{\cdot}s^{-2}$ (Rennie et al., 2020; Tahsin et al., 2015), leading to the removal of 54 tackle events. Providing a final total of 214 observations. Once tackles were accepted for analysis, time derivatives of speed and acceleration could be calculated using instantaneous 10 Hz speed and acceleration data. Average speed over the 0.5 s preceding the tackle was used, along with average acceleration ($m{\cdot}s^{-2}$) for the time period which was calculated by $a = (v\text{-}u)/t$ whereby v and u represent final and initial speed respectively and t represents time, which in this case was 0.4, as there were only four intervals of acceleration.

Statistical analysis

Descriptive statistics of running speed and acceleration into tackles are presented as mean ± standard deviation (SD) for both ball-carriers and tacklers. Linear mixed effects modelling fit by Restricted Maximum Likelihood (REML) via the *lme4* package (version 1.1–26) (Bates et al., 2015) were implemented to investigate the differences between ball-carrier and tackler overall and by positional group. Average speed ($m{\cdot}s^{-1}$) and acceleration ($m{\cdot}s^{-2}$) during the pre-contact phase (contact − 0.5 s) were the dependent variables. All dependent variables were log-transformed prior to analysis and subsequently back transformed to reduce error arising from non-uniform residuals (Hopkins et al., 2009). Role within the tackle (ball-carrier or

Table 1. Description (mean ± SD) and comparison of mean speed ($m{\cdot}s^{-1}$) and acceleration ($m{\cdot}s^{-2}$) into contact during the pre-contact phase (contact −0.5 s) as ball-carrier and tackler overall and for positional interactions.

	Speed ($m{\cdot}s^{-1}$) (mean ± SD)				Acceleration ($m{\cdot}s^{-2}$) (mean ± SD)			
Comparison	Ball-carrier	Tackler	Effect Size (90% CI)	*p*	Ball-carrier	Tackler	Effect Size (90% CI)	*p*
Ball-carrier vs Tackler	4.73 ± 1.12	2.82 ± 1.07	*Large* 1.69 (1.48 to 1.89)	<0.001	0.67 ± 1.01	−1.26 ± 1.36	*Large* 1.74 (1.54 to 1.93)	<0.001
Back vs Back	5.23 ± 0.84	2.71 ± 0.78	*Large* 1.58 (1.32 to 2.07)	<0.001	0.88 ± 0.66	−1.05 ± 1.25	*Large* 1.91 (1.54 to 2.28)	<0.001
Back vs Forward	4.76 ± 1.41	2.86 ± 1.03	*Large* 1.24 (0.47 to 2.18)	<0.001	0.59 ± 0.94	−1.33 ± 1.38	*Very Large* 2.31 (1.81 to 2.82)	<0.001
Forward vs Back	4.87 ± 0.71	2.71 ± 1.04	*Large* 1.59 (1.09 to 2.30)	<0.001	0.71 ± 0.96	−0.79 ± 1.36	*Large* 1.49 (1.24 to 1.74)	0.002
Forward vs Forward	4.58 ± 0.98	2.83 ± 1.16	*Large* 1.61 (1.44 to 1.99)	<0.001	0.66 ± 1.09	−1.31 ± 1.37	*Large* 1.97 (1.25 to 2.69)	<0.001

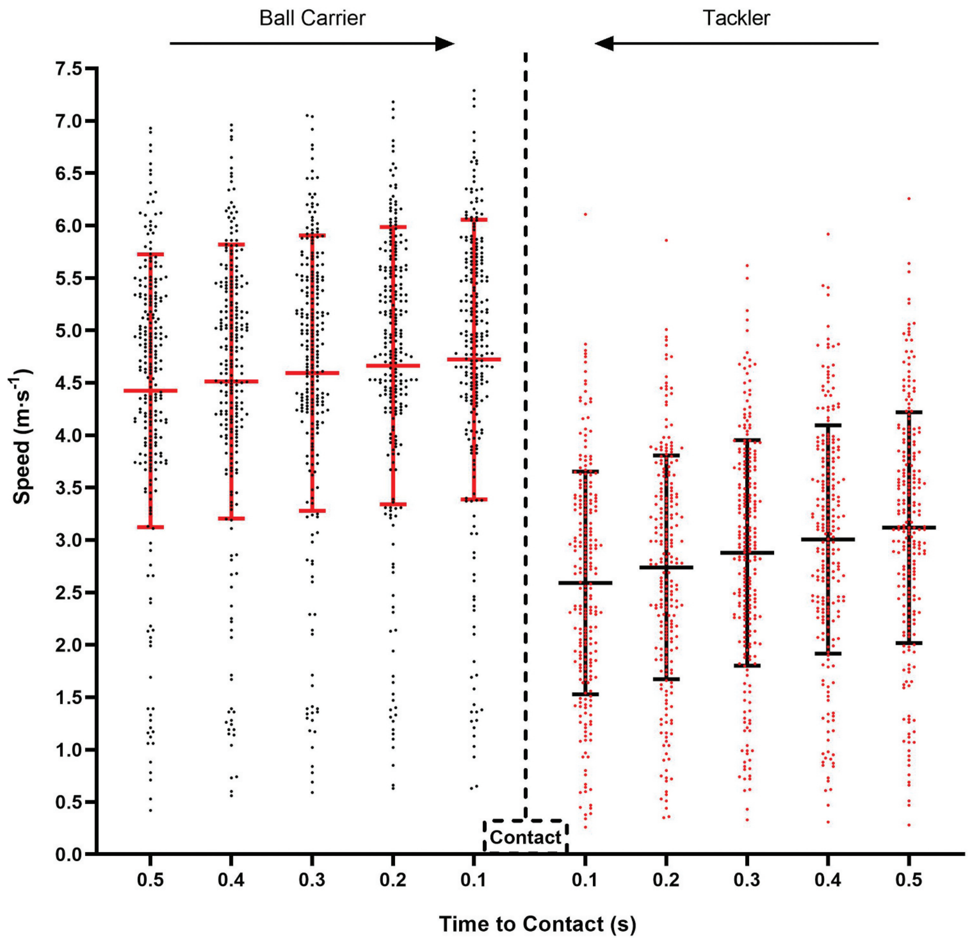

Figure 3. Speed (m·s^{-1}) for ball-carrier and tackler at 0.1s intervals preceding contact (mean ± SD).

tackler) and its interaction with their positional group (forward or back) were defined as the fixed effects and between-player as a random intercept. Cohen's d effect size (ES) statistics (Cohen, 2013) with 90% confidence intervals were estimated from the ratio between the mean difference to the pooled standard deviation for the fixed effect. ES was interpreted as <0.20 = trivial, 0.20–0.59 = small, 0.60–1.19 = moderate, 1.20–2.00 = large, >2.00 = very large (Batterham & Hopkins, 2006; Cohen, 1992). Null hypothesis testing was used to determine statistical significance ($P < 0.05$).

Results

Mean ± SD and pairwise comparisons for speed and acceleration for ball-carrier and tackler for the pre-contact phase (contact − 0.5 s) are shown in Table 1. There were *large* differences in speed (ES range = 1.58 to 1.69, p = <0.001) and acceleration (ES range = 1.49 to 2.31 p = <0.001 to 0.002) between ball-carrier and tackler overall and for all positional interactions. Mean ± SD for speed for ball-carrier and tackler at 0.1 s intervals preceding contact are shown in Figure 3, which highlights ball-carriers greater speed and acceleration compared to tacklers during the pre-contact phase of the tackle.

The speed and acceleration for each individual tackle event are shown in Figure 4. Ball-carrier speed was greater than tackler speed during 88% of observed tackles. When separated by position, the speed of the ball-carrier was greater than the tackler on 96% of events involving a back ball-carrier vs. back tackler, 86% for back ball-carrier vs. forward tackler, 92% for forward ball-carrier vs. back tackler and 87% for forward ball-carrier vs. forward tackler.

Comparisons between ball-carrier and tackler by positional group for mean speed, and acceleration during the pre-contact phase (contact − 0.5 s) are shown in Figure 5. There was a greater ball-carrier speed during back vs. back tackle events than forward vs. forward tackle events (*moderate*; ES = 0.66, p = 0.01). Furthermore, there was a greater ball-carrier speed by backs during back vs. forward tackle events than forward vs. forward tackle events (*small*; ES = 0.40, p = 0.02). All other comparisons showed non-significant differences ranging from *trivial* to *small*.

Discussion

The aim of the study was to compare the speed and acceleration of the ball-carrier and tackler including positional interactions during the pre-contact phase (contact − 0.5 s) of front-on

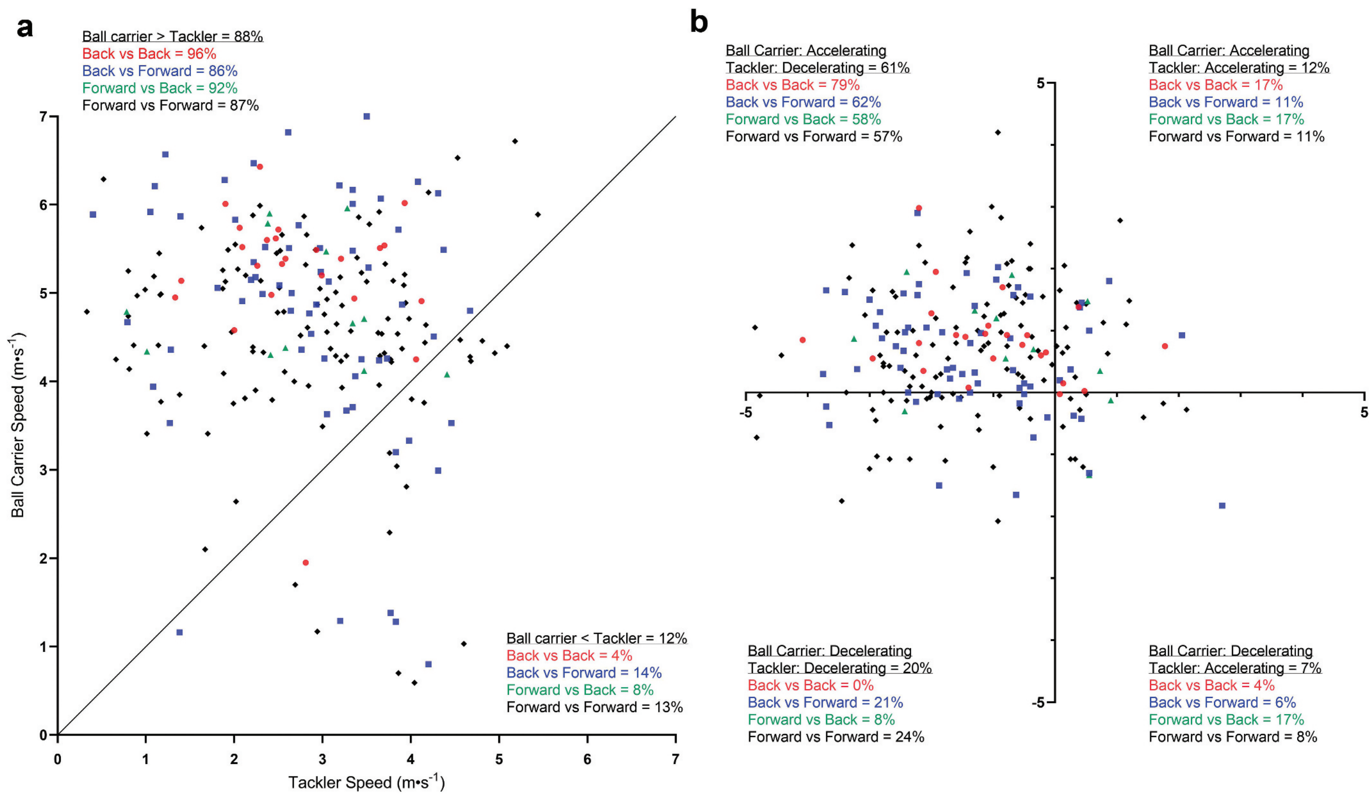

Figure 4. Mean speed (a) and acceleration (b) during the pre-contact phase (contact −0.5s) for ball-carrier and tackler during each individual tackle event, tackles are also separated by positional group (ball-carrier vs tackler) ● = back vs back, ■ = back vs forward, ▲ = forward vs back, ◆ = forward vs forward.

tackles during Super League match play. Overall, mean ball-carrier speed (4.73 ± 1.12 m·s^{-1}) was significantly greater than tackler speed (2.82 ± 1.07 m·s^{-1}), with ball-carrier speed exceeding tackler speed in 88% of tackles (Figure 4). The ball-carrier accelerated (mean = 0.67 m·s^{-2}) whilst the tackler decelerated (mean = −1.26 m·s^{-2}) into tackles. Positional comparisons of forwards and backs overall show no difference in speed and acceleration during ball-carries or tackles. However, assessments of positional interactions show that ball-carrier speed was greater when backs carried the ball into tackles (back vs. forward = 4.76 m·s^{-1}; back vs. back = 5.23 m·s^{-1}) than when forwards are tackled by forwards (forward vs. forward = 4.58 m·s^{-1}). These findings provide practitioners and policy makers with greater detail regarding the tackle event in rugby league. Such information can be used to aid practitioners to ensure players are adequately prepared for the demands of match-play e.g., the deceleration demands of the tackler, whilst being useful to policy makers to make informed decisions when reviewing the rules regarding the tackle.

The current study finding of greater speed for ball-carriers (4.73 ± 1.12 m·s^{-1}) than tacklers (2.82 ± 1.07 m·s^{-1}; Table 1) is different from that previously reported in professional rugby union. Hendricks et al. (2012) reported no differences between ball-carriers (4.8 ± 2.9 m·s^{-1}) and tacklers (5.0 ± 1.8 m·s^{-1}) with ball-carriers and tacklers both decelerating into contact. In contrast, in rugby league, the current study found ball-carriers to accelerate (mean = 0.67 ± 1.01 m·s^{-2}) whilst tacklers decelerate (mean = -1.26 ± 1.36 m·s^{-2}; Figure 3) into contact. Such differences between sports are likely attributed to rule and tactical differences. In rugby league, defensive players must retreat 10 m from the ruck following the tackle whereas in rugby union, defensive players must retreat behind the hind-most player in the ruck. In rugby league, the ball-carrier can initiate their carry from any distance behind the ruck providing greater opportunity for the ball-carrier to accelerate and increase speed into the tackle. Relative to the ball-carrier, the 10 m defensive retreat likely provides the tackler with less opportunity to accelerate and increase their speed before preparing themselves to enter the tackle event. In addition, it is likely that the tackler must balance their speed into contact to restrict gained territory by the ball-carrier (i.e., defensive-line speed) with their individual technical ability to complete a successful tackle. By decelerating into contact, this might allow the tackler to better execute changes in body position in anticipation of potential evasion by the ball-carrier. Given the frequency of tackle events whereby the tackler is decelerating prior to contact, deceleration exposure should be included within a holistic monitoring strategy. Furthermore, practitioners should ensure players have adequate deceleration capability for the demands of match-play (Harper & Kiely, 2018). An understanding of deceleration capability as a determinant of tackle performance would provide useful information regarding the tackle event, previous studies have attempted to understand the interaction between physical characteristics (e.g., speed, power, maximal speed, acceleration), and technical abilities and success within the tackle in rugby league (Gabbett

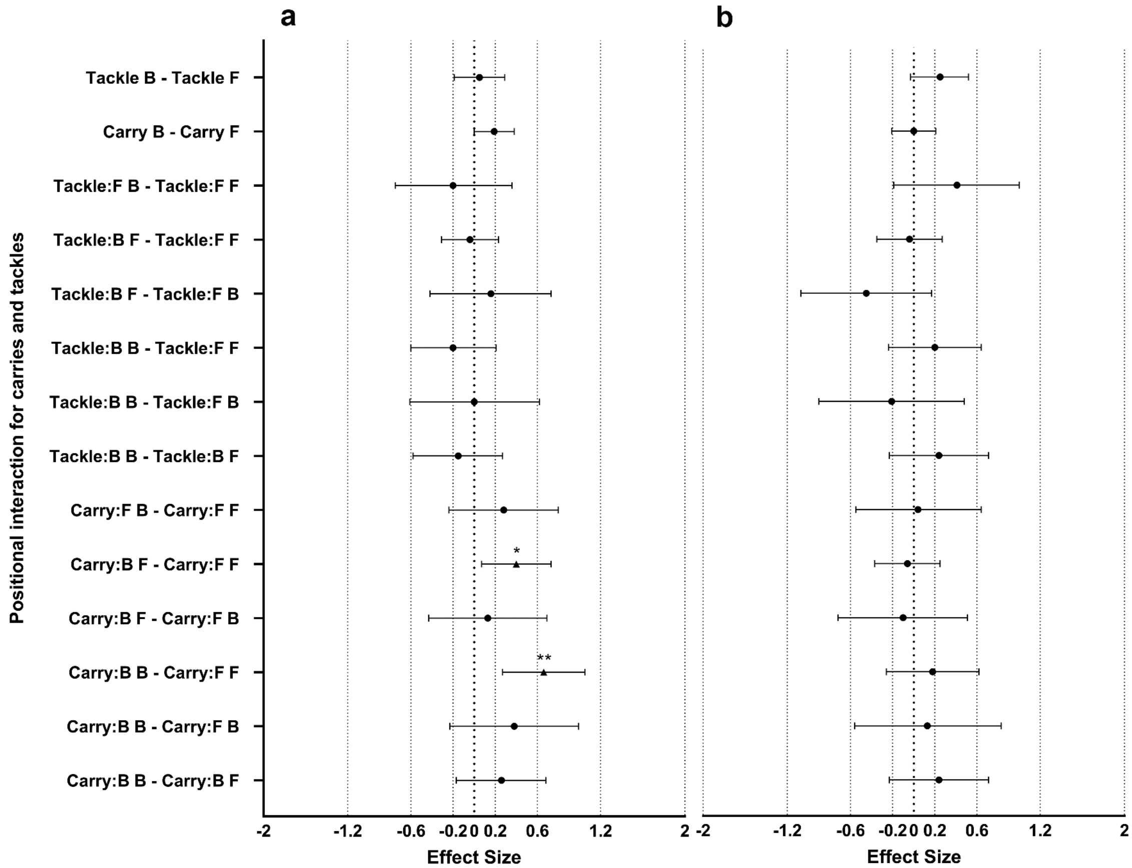

Figure 5. Pairwise comparisons of mean (a) speed (m·s^{-1}) and (b) acceleration (m·s^{-2}) into contact during the pre-contact phase (contact −0.5s) for different positional groups (forwards and backs) during carries and tackles. Represented using effect size 90% CI. Statistically significant comparisons are represented as ▲, while non-significant comparisons are represented as ●. * = P ≤ 0.05, ** = P ≤ 0.01.

et al., 2011; Speranza et al., 2017). Despite the identified importance of deceleration within the tackle, further research is warranted to understand the relationship between deceleration capability and tackle success, given the highlighted importance of deceleration during the pre-contact phase of the tackle in the current study, this could be an important area to understand for both performance and welfare perspectives.

Overall, the mismatch in speed between ball-carrier and tackler speed (Figure 4) also highlights considerations for the technical aspects of the tackle, with tacklers having a reduced window to execute proper tackling technique leading to potentially negative outcomes (e.g., head collision or injury). This mismatch suggests the closing velocities between ball-carrier and tackler are frequently dictated by the ball-carrier rather than the tackler. The risk of injury and greater inertial head kinematics and neck dynamics from the rugby union tackle, for both the ball-carrier and tackler increases when the speed increases for both groups (Quarrie & Hopkins, 2008; Tierney & Tucker, 2022). The risk of concussion during tackle events has been linked acceleration into contact within rugby union, with the acceleration of the tackler or both tackler and ball-carrier combined providing an increased concussion risk when compared to ball-carrier (Cross et al., 2019). The present study found that tacklers accelerate into contact during 19% of the tackles analysed and both ball-carrier and tackler were found to accelerate during 12% of tackles analysed. As such, particular focus from both a player performance and welfare perspective should be placed on match event situations that lead to tackle events with a high closing-speed (tackle events where both ball-carrier and tackler speed are high) or when the tackler or both ball-carrier and tackler are accelerating into contact.

Positional comparisons between forwards and backs show no overall difference in speed or acceleration for carries or tackles (B-F, Figure 5). Ball-carrier speed was significantly greater when backs carry into tackles (Carry: BF and Carry: BB) than when forwards tackle forwards (Carry: FF). There are numerous factors that could potentially explain this difference within the rugby league. One potential factor would be differences in physical capabilities between the two groups with backs likely faster over 10 and 40 m (Lacey et al., 2014). This greater speed capability could allow backs to potentially achieve higher velocities during the pre-contact phase of the tackle. Anthropometric differences between forwards and backs, with forwards having a greater body mass when compared to backs also may contribute to differences between positional groups (Lacey et al., 2014). The momentum of a player into contact is directly proportional to mass and velocity i.e., when velocity or mass increases as does the momentum providing the remaining components of the equation ($p =$ mv) remain constant. Differences in momentum between ball-carrier and tackler have been previously hypothesised to lead increased injury risk (Hendricks et al., 2014), as such the back as a ball-carrier increases speed in order to increase momentum in an attempt to overcome the mass advantage of the tackler.

Similarly, a reduced ball-carrier speed is seen when forwards tackle forwards to reduce momentum and subsequent injury risk. Contextual game factors influencing ball-carrier and tacker speed may also provide an explanation for the difference. For example, it is possible that the context in which backs carry into tackles for example following kick returns provides greater space and opportunity to reach higher velocities. Future studies should look to investigate the effect of contextual factors (e.g., field position and tackle number within the set) on ball-carrier and tackler speed interactions.

Limitations

The current study is not without limitations. Firstly, no anthropometric data were included and analysed within the study therefore any inferences made regarding momentum or energy transfer within the tackle are speculation. Secondly, the present study only assessed front-on tackles within rugby league given the increased injury risk of these events and theoretical increased magnitude of these events, therefore it is not appropriate to use the data provided to make informed decisions regarding tackle types not explored within the study for example side on tackles. Along with this, the present study only assessed on the first contact between ball-carrier and tackler and did not include data on subsequent tacklers joining the same tackle event.

Future directions

As previously stated within the study, there are no currently established dose–response relationships between speed and acceleration and potential negative consequences of the tackle in rugby league, therefore any inferences made are speculative. As such, future research should focus on establishing dose–response relationships between ball-carrier speed and acceleration and the consequences of the tackle e.g., head kinematics and concussion. Along with this, assessments of contextual factors relating to the speed and acceleration during the tackle such as the time of the game and the effect of fatigue as well as assessing the effect of interchanges would be key for policy makers to make informed decisions regarding the game. Finally, an analysis of how the speed and acceleration into contact relate to tackle dominance and success could be of particular interest to coaching and performance staff making technical and tactical decisions within practice.

Conclusion

Overall, ball-carriers travel at higher speeds than tacklers into tackles during the pre-contact phase (contact – 0.5 s) of front-on tackles during Super League match play. Ball-carriers generally accelerate into contact whilst tacklers decelerate. Positional comparisons show that backs are more likely to have greater ball-carrier speed when compared to when forwards tackle forwards, this is likely influenced by physical and anthropometric differences between positional groups along with positional specific contextual factors regarding each carry. Practically, the insights presented within this study could be beneficial to backroom staff and governing bodies within rugby league. Practitioners can use the data provided when assessing the demands of rugby league match-play and aid training prescription to ensure that players are adequately prepared for the demands of match play. Governing bodies can also use these data to inform injury prevention interventions associated with the tackle. For example, currently most interventions are aimed at the tackler, but given that higher speed into contact leads to increased head kinematics (Tierney & Tucker, 2022), and ball-carriers generally increase the closing speed of the tackle, specific interventions may now focus on the ball-carrier, although contextually this may be challenging to implement.

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