Are recommended tackle techniques associated with superior performance outcomes? A retrospective video analysis study of elite women's rugby union

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Abstract

This cross-sectional study aims to identify the situational characteristics, ball-carrier technical variables, and *Tackle Ready* recommended techniques associated with performance outcomes in elite women's Rugby Union. Using retrospective video analysis, 43 tackler and ball-carrier technical characteristics for 1500 tackle events in the 2022–23 Women's Six Nations Championship were assessed, considering match situation and performance outcomes. Rate ratio (RR) was determined using propensity rates. Effective tackles were associated with match situations involving two defenders, forwards tackling forwards, defensive teams moving forwards, and tackles initiated closer to attackers at ball reception. Seven out of the 22 coded *Tackle Ready* techniques were significantly associated with superior performance outcomes. Techniques associated with the greatest likelihood of effective tackle outcome included wrap and clamp (RR 46.8) and ear to body (RR 20.9). Tackles made to the hip and leg of the ball-carrier increased the risk of missed tackles. This study provides the first analysis of tackle characteristics associated with performance outcomes in women's rugby, providing a reference to inform coaching practice and the implementation of tackle education resources and law changes. Further research is warranted to explore techniques associated with injury risk, and interactions between match situations and subsequent tactical/technical tackle actions.

Keywords: Rugby union; tackle; video analysis; women; performance

Introduction

Women's rugby union (henceforth "rugby") is one of the fastest-growing sports worldwide, with participation rising by approximately 28% per year (World Rugby, 2020). Rugby is a sport characterised by tackle events involving one or more defenders attempting to stop ball-carrying attacking players from gaining territory and scoring points (Hendricks et al., 2020; Scott et al., 2023). A player's tackle performance is a product of not only their physical, psychological, and tactical capacity but also their

technical ability (Dane,, Foley, Hendricks, et al., 2023; Hendricks, van Niekerk, et al., 2018). The frequency (averaging 280 events per match at the Canadian varsity level) (West et al., 2022), and physical-technical nature of the tackle makes it the most injurious match contact event in rugby (Starling et al., 2023). Therefore, mitigating the risk of tackle injuries is a top priority for rugby stakeholders and governing bodies including World Rugby.

Research has identified tackle techniques associated with performance outcomes and risk factors for injury (Hendricks, van Niekerk, et al., 2018; McLeod et al., 2023; Shill et al., 2024). In training or matches, coaches can quantitatively assess these techniques, providing feedback on which techniques/technical areas to prioritise (Hendricks, van Niekerk, et al., 2018). Furthermore, video analysis of tackle technique, performance and injury outcomes have been used to inform the development of tackle safety education programmes, including World Rugby's *Tackle Ready* resource (World Rugby, 2022a). In practice, the adoption of recommended techniques is likely shaped by contextual determinants of the performance setting and the attitudes and practices of the stakeholders' (e.g., players' and coaches') who are implementing them (Dane, West, Hendricks, et al., 2024; McKay & Verhagen, 2016). Qualitative research has highlighted the centrality of performance to players' and coaches' perceptions and practices in relation to injury prevention (Dane, Foley, & Wilson, 2023; Vella et al., 2022). Therefore, a pivotal consideration when designing and implementing tackle safety programmes is whether recommended tackle techniques (e.g., *Tackle Ready*) contribute to team performance outcomes.

Despite the rapid growth and professionalisation of women's rugby (World Rugby, 2020), women rugby players feature in less than 4% of the tackle research (Burger et al., 2020). As such, it is likely that tackle safety frameworks are informed by, developed and tested in men's rugby contexts. An overreliance on male-derived frameworks may be misaligned to the effective preparation of women rugby players as they can commonly overlook differences in physical, technical and tactical aspects of match play between men's and women's rugby (Dane et al., 2022; Williams et al., 2022). Furthermore, the wider gendered sociocultural environments in which women rugby players operate should be considered (Dane, Foley, Hendricks, et al., 2023). To better inform coaching and policy that align with the women's rugby playing context, an analysis of the tackle technical characteristics associated with performance in women's rugby is required. Therefore, the purpose of this study is to identify the match situational characteristics, ball-carrier technical variables, and *Tackle Ready* recommended tackler techniques associated with performance outcomes in elite women's rugby.

Materials and methods

Study design

This retrospective cross-sectional study formed part of a larger project investigating the technical characteristics of match tackle events in elite women's rugby (Dane, West, Simms, et al., 2024). The reporting of the study follows the "Strengthening the Reporting of Observational studies in Epidemiology" (STROBE-SIIS recommendation) (Bahr et al., 2020) (Supplementary table S1).

Analysis framework

A tackle was defined as "an event where one or more tacklers (player or players making the tackle) attempt to stop or impede the ball-carrier (player carrying the ball) whether or not the ball-carrier was brought to ground" (Hendricks et al., 2020).

An analysis framework of three categories: match situation, technical characteristics of tackler and ball-carrier, and performance outcomes was developed and adapted from the Rugby Union Video Analysis

Consensus (RUVAC) framework (Hendricks et al., 2020), and the *Tackle Ready* framework (World Rugby, 2022a). In total, 43 variables were identified and described (Supplementary table 2). World Rugby's *Tackle Ready* framework includes 36 "key performance indicators" (KPIs). Fourteen of the recommended techniques, such as "iron grip", "hip and core activation", "communication" and "react and reshape", were excluded from consideration as they could not be assessed visually from match video footage. Therefore, 22 of the 36 *Tackle Ready*-recommended techniques were mapped into the pre-contact, contact and post-contact phases (World Rugby, 2022a) (Figure 1). Technical characteristics were split into three main phases pre-contact (≈1s preceding contact), contact (first instance of contact) and post-contact.

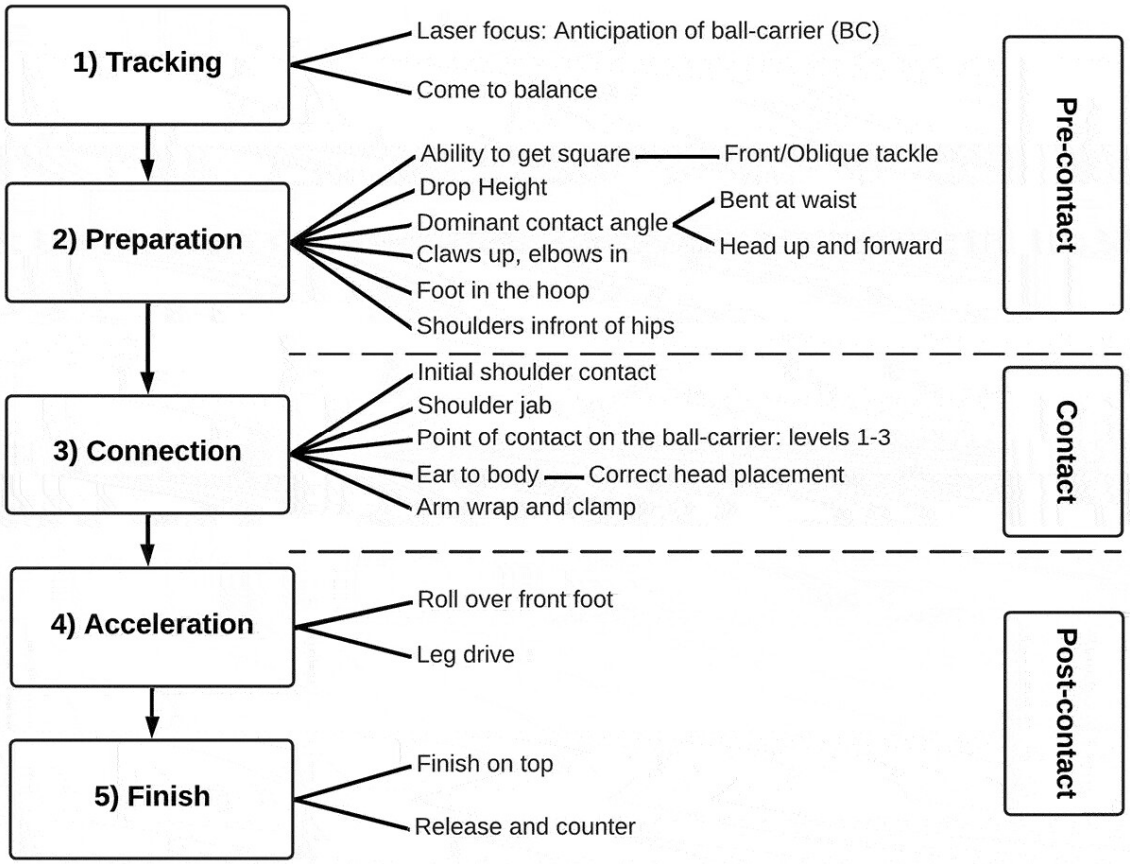

Figure 1. The 22 coded *tackle ready* variables and five stages of World Rugby's *tackle ready* framework mapped into the pre-contact, contact and post-contact phases (World Rugby, 2022a). (BC ball-carrier).

Tackle performance of outcomes were defined according to the RUVAC consensus statement and *Tackle Ready* KPI's (Figure 2) (Hendricks et al., 2020; World Rugby, 2022a). To better translate the analysis framework and performance outcomes into the women's rugby performance setting, an expert group of coaching stakeholders (n = 5) from Europe, South Africa, and New Zealand offered independent assessment on the clarity, relevance and validity of the performance outcomes and definitions. Coaching experts were selected via an outreach strategy involving direct communication with key administrative figures from Rugby Unions who possessed extensive networks and connections with coaches and educators. This outreach leveraged existing relationships and affiliations to effectively identify and engage coaching stakeholders for informal consultation. Experience within this expert group included: coach education, rugby policy, refereeing, rugby administration, sports physiotherapy (including rugby),

sports science, and elite rugby playing experiences. Following informal consultation, the definitions of two technical variables were modified for wording.

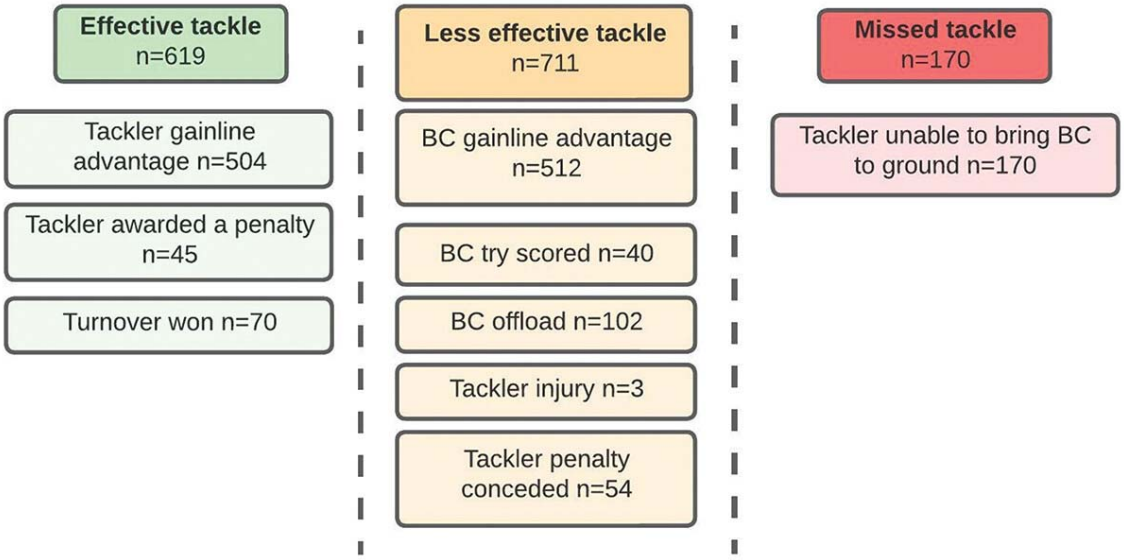

Figure 2. Diagram of identification process of performance outcomes.

Video collection of match data

A random sample of 1500 tackle events from all fifteen games from the 2022–23 Women's Six Nations Championship were analysed retrospectively. A tackle involving two tacklers was coded as two tackle events. All 5260 tackle events across all fifteen games were screened for visual quality by the first author (KD) (Stats Perform, 2022). Tackle events were excluded if the footage was not clear enough to accurately code technical characteristics (n = 251 tackle events removed). From the remaining total tackle events (n = 5009), a randomisation tool was used to generate 1500 unique numbers. Tackle events matching the randomly allocated numbers were coded. Quota sampling was used to ensure relatively equal distribution of tackle events by team, time of competition and match quarter. The distribution of missed tackles was comparable (11% versus 14%) to a study of the men's Six Nations Championship (van Rooyen et al., 2014).

There was a minimum of four camera views available from broadcast quality footage for each tackle event. Each camera was able to slow down to 25 frames per second. Match video footage was analysed either at full-speed or frame-by-frame using Sports Code (Sportscode Elite, V.10.3.36, Sportstec, France) on an Apple Macbook (Apple Inc., Cupertino, California USA). Permission to use this video footage for the purposes of anonymous video-analysis for research was obtained from the Irish Rugby Football Union and Six Nations Rugby. Video footage was obtained from the video and production manager.

To eliminate any intercoder variability, a single analyst (KD) with experience of playing and coaching elite women's rugby examined all 1500 tackle events. Intra- and inter-coder reliability testing was completed using Cohen's kappa (κ) in SPSS (Cohen, 1960). The testing process has been reported in greater detail elsewhere (Dane, West, Simms, et al., 2024). The original coder and two external reviewers (Biomedical Engineer (CS) and Elite Rugby Performance Analyst (COB)) analysed ten randomly selected video clips. The κ statistic results for intercoder reliability were κ = 1 (match situational variables), κ = 0.90 (pre-contact), κ = 0.94 (contact), κ = 0.98 (post-contact), κ = 0.99 (tackle outcomes). The κ statistic results for

intracoder reliability were κ = 1 (match situational variables), κ = 0.95 (pre-contact), κ = 0.95 (contact), κ = 0.98 (post-contact), κ = 1 (tackle outcomes).

Statistical analysis

The frequency of tackle characteristics was reported as count and proportions. The propensity rate (PR), such as effective tackle events from a characteristic per 1000 tackles, was calculated by dividing the number of effective events occurring from a characteristic by the total number of effective tackle events and multiplying by one thousand. For each characteristic, the Rate Ratio (RR) and 95% confidence interval (CI) were calculated to compare the propensity of two events by expressing the performance outcome propensity relative to one another. The statistical significance threshold *p* value was adjusted for the multiple comparisons according to the Bonferroni method. For example, with 72 comparisons for the *Tackle Ready* recommended techniques, this yields Bonferroni-corrected significance level of 0.05/72 = 0.000694. A Chi-squared, Phi and Cramer's V calculation was also conducted; 95% CIs were used based on the Poisson distribution. A Phi and Cramer's V value less than 0.1, between 0.1 and 0.3, between 0.3 and 0.5 and 0.5 or greater are indicative of a trivial, small, moderate and large effect size respectively (Cohen, 1960). A characteristic was considered to have statistical significance if the 95% CIs did not overlap and the *p* value from the Chi Square calculation was < 0.05. All analysis was undertaken in STATA 18 (StataCorp, 2019, Stata Statistical Software, College Station, TX: StataCorp LLC).

Results

There was a mean of 282.6 completed tackles per match across the championship (95% CI 194.3–370.9) (Supplementary table 3).

Situational characteristics and tackle performance

The distribution of tackle situational characteristics is presented in Table 1. The likelihood of an effective tackle significantly decreased for tackles following restarts (RR 0.37, 95% CI 0.2–0.7, *p* = 0.00, ES=small) and for tackles made after the attacking team completed 4–6 passes (RR 0.24, 95% CI 0.12–0.46, *p* = 0.00, ES=small).

The probability of an effective tackle significantly increased when the defensive team was moving forwards (RR 1.58, 95% CI 1.25–2.01, p = 0.00, ES=small) when compared to defensive teams moving lateral (RR 0.66, 95% CI 0.45–0.99, p = 0.04, S=small), backwards (RR 0.54, 95% CI 0.30–0.97, p = 0.00, ES=small) or with no clear direction (RR 0.29, 95% CI 0.16–0.51, p = 0.00, ES=small). Tackles involving a forward tackling another forward (RR 2.03, 95% CI 1.49–2.83, p = 0.00, ES=small), as opposed to events involving backs tackling backs (RR 0.58, 95% CI 0.42–0.81, p = 0.00, S=small), backs tackling forwards (RR 0.57, 95% CI 0.38–0.86, p = 0.01, ES=small) or forwards tackling backs (RR 0.75, 95% CI 0.48–1.19, p = 0.19, ES=small), significantly increased the likelihood of an effective tackle. Defensive sequential tackles (2v1) (RR 26.5, 95% CI 8.96–129.0, p = 0.00, ES=small) significantly increased the likelihood for effective tackles when compared to 1v1 tackles or tackles that involved a second attacker (1v2). The probability of effective tackles increased when the tackler was near (RR 1.75, 95% CI 1.14–2.78, p = 0.00, ES=small) or a moderate distance from the ball-carrier at ball reception (RR 1.36, 95% CI 1.04–1.80, p = 0.02, ES=small) when compared to tackles where the ball-carrier approached from a distance.

Table 1. Match situational variables for effective tackles versus missed tackles (includes % occurrence, rate ratios (RR) with 95% confidence intervals (95% CI), phi and Cramer's V and interpretations).

Situational variables	Effective tackles (*n*=619)	Less effective tackles (*n*=711)	Missed tackles (*n*=170)	RR effective versus missed (95% CI)	RR effective versus less effective (95% CI)	RR less effective versus missed (95% CI)	Phi and Cramer's V[a]	Interpretation
Team ranking								
Top 3 teams (*n*=740)	304 (41%)	358 (48%)	78 (11%)	1.07 (0.83–1.39)	1.02 (0.88–1.20)	1.10 (0.86–1.42)	<0.1	trivial
Bottom 3 teams (*n*=760)	314 (42%)	353 (46%)	92 (12%)	0.94 (0.74–1.20)	1.02 (0.87–1.19)	0.92 (0.73–1.17)	<0.1	trivial
Previous phase								
Unstructured (*n*=1073)	499 (47%)	457 (43%)	117 (10%)	0.12 (0.03–0.26)	**1.25*(1.10–1.43)**	0.93 (0.76–1.15)	0.13	small
Restart (*n*=106)	27 (25%)	59 (56%)	20 (19%)	0.37 (0.2–0.7)	0.53 (0.32–0.84)	0.71 (0.42–1.24)	0.13	small
Scrum (*n*=130)	35 (27%)	84 (65%)	11 (8%)	0.87 (0.43–1.91)	**0.48*(0.31–0.72)**	1.83 (0.97–3.80)	0.13	small
Lineout (*n*=191)	58 (30%)	111 (58%)	22 (12%)	0.72 (0.44–1.24)	0.60 (0.43–0.83)	1.21 (0.76–2.0)	0.13	small
Pass number								
0–3 passes (*n*=1403)	601 (43%)	653 (47%)	149 (10%)	1.11 (0.92–1.33)	1.06 (0.94–1.18)	1.05 (0.88–1.26)	0.16	small
4–6 passes (*n*=97)	18 (18%)	58 (60%)	21 (22%)	**0.24*(0.12–0.46)**	**0.36*(0.2–0.61)**	0.66 (0.39–1.15)	0.16	small
Match quarter								
1st quarter (*n*=353)	159 (45%)	159 (45%)	35 (10%)	1.25 (0.86–1.85)	1.15 (0.92–1.44)	0.97 (0.68–1.42)	<0.1	trivial
2nd quarter (*n*=393)	159 (40%)	187 (48%)	47 (12%)	0.93 (0.67–1.32)	0.98 (0.79–1.21)	0.95 (0.69–1.34)	<0.1	trivial
3rd quarter (*n*=395)	160 (41%)	188 (48%)	47 (11%)	0.93 (0.67–1.32)	0.98 (0.79–1.21)	0.96 (0.69–1.35)	<0.1	trivial
4th quarter (*n*=359)	141 (39%)	177 (49%)	41 (12%)	0.94 (0.66–1.37)	0.92 (0.73–1.15)	1.03 (0.73–1.49)	<0.1	trivial
Defensive direction								
Forwards (*n*=894)	489 (55%)	320 (36%)	85 (9%)	**1.58*(1.25–2.01)**	**1.76*(1.52–2.03)**	0.9 (0.71–1.16)	0.25	small
Lateral (*n*=301)	94 (31%)	168 (56%)	39 (13%)	0.66 (0.45–0.99)	**0.64*(0.49–0.83)**	1.03 (0.72–1.50)	0.25	small
Backwards (*n*=102)	9 (8%)	73 (72%)	20 (20%)	**0.12*(0.05–0.28)**	**0.14*(0.06–0.28)**	0.87 (0.53–1.51)	0.25	small
No direction (*n*=203)	27 (13%)	150 (74%)	26 (13%)	**0.29*(0.16–0.51)**	**0.21*(0.13–0.31)**	1.38 (0.91–2.18)	0.25	small
Tackle sequence								
1v1 (*n*=755)	240 (32%)	349 (46%)	166 (22%)	**0.40*(0.32–0.49)**	0.79 (0.67–0.93)	**0.36*(0.29–0.44)**	0.25	small
1v2 (*n*=28)	14 (50%)	14 (50%)	0	-	1.15 (0.51–2.60)	-	0.25	small
Defensive Sequential (2v1) (*n*=591)	289 (49%)	299 (51%)	3 (0.5%)	**26.5*(8.96–129)**	1.11 (0.94–1.31)	**23.8*(8.08–116)**	0.25	small
Defensive Simultaneous (2v1) (*n*=38)	20 (53%)	18 (47%)	0	-	1.28 (0.64–2.56)	-	0.25	small
Defensive Sequential, (2v2) Attacking Sequential (*n*=72)	44 (61%)	27 (38%)	1 (1%)	**12.1*(2.06–488)**	1.87 (1.13–3.14)	6.46 (1.06–264)	0.25	small

Defensive Simultaneous, (2v2) Attacking Sequential (n=16)	12 (75%)	4 (25%)	0	-	3.45 (1.04–14.7)	-	0.25	small
Distance from ball-carrier								
Near (n=328)	159 (48%)	144 (44%)	25 (8%)	1.75 (1.14–2.78)	1.27 (1.01–1.60)	1.38 (0.90–2.20)	0.15	small
Moderate (n=663)	321 (48%)	277 (42%)	65 (10%)	1.36 (1.04–1.80)	**1.33*(1.13–1.57)**	1.02 (0.78–1.36)	0.15	small
Distant (n=509)	139 (27%)	290 (57%)	80 (16%)	**0.48*(0.36–0.64)**	**0.55*(0.45–0.68)**	0.87 (0.67–1.12)	0.15	small
Positional groupings (tackler vs. ball-carrier)								
Back vs. Back (n=435)	121 (28%)	257 (59%)	57 (13%)	0.58 (0.42–0.81)	**0.54*(0.43–0.67)**	1.08 (0.81–1.46)	0.18	small
Back vs. Forward (n=203)	79 (39%)	86 (42%)	38 (19%)	0.57 (0.38–0.86)	1.06 (0.77–1.45)	0.54 (0.37–0.81)	0.18	small
Forward vs. Forward (n=656)	340 (52%)	270 (41%)	46 (7%)	**2.03*(1.49–2.83)**	**1.45*(1.23–1.70)**	1.40 (1.02–1.96)	0.18	small
Forward vs. Back (n=206)	79 (38%)	98 (48%)	29 (14%)	0.75 (0.48–1.19)	0.93 (0.68–1.26)	0.81 (0.53–1.27)	0.18	small
Defensive team performance								
Winning (n=665)	296 (44%)	296 (45%)	73 (11%)	1.11 (0.86–1.46)	1.15 (0.97–1.35)	0.97 (0.75–1.27)	<0.1	trivial
Losing (n=541)	181 (33%)	284 (52%)	76 (15%)	0.65 (0.50–0.87)	0.73 (0.60–0.89)	0.89 (0.69–1.17)	<0.1	trivial
Drawing (n=294)	142 (48%)	131 (45%)	21 (7%)	1.86 (1.17–3.09)	1.25 (0.97–1.59)	1.49 (0.94–2.49)	<0.1	trivial

Statistically significant Bonferroni-corrected p-values in bold with asterisk ($p < 0.000521$). RR rate ratio, BC ball-carrier, CI confidence intervals, [a] N.B. for effective versus missed tackles. Dash represents too few values to facilitate RR calculations.

Ball-carrier characteristics and tackle performance

Supplementary table 4 shows the ball-carrier technical characteristics associated with missed tackles versus effective tackles. During pre-contact, when the ball-carrier was upright (RR 1.47, 95% CI 1.18–1.82, $p = 0.00$, ES=small) or ran at high speed (RR 2.10, 95% CI 1.70–2.59, $p = 0.00$, ES=small) or performed a side-step (RR 1.68, 95% CI 1.28–2.19, $p = 0.00$, ES=small) the probability of a missed tackle significantly increased. In the contact and post-contact phases, the likelihood of a missed tackle also significantly increased when the ball-carrier fended (RR 1.54, 95% CI 1.24–1.91, $p = 0.00$, ES=small) or used leg drive (RR 1.57, 95% CI 1.30–1.88, $p = 0.00$, ES=small) when compared to tackles without leg drive or fending.

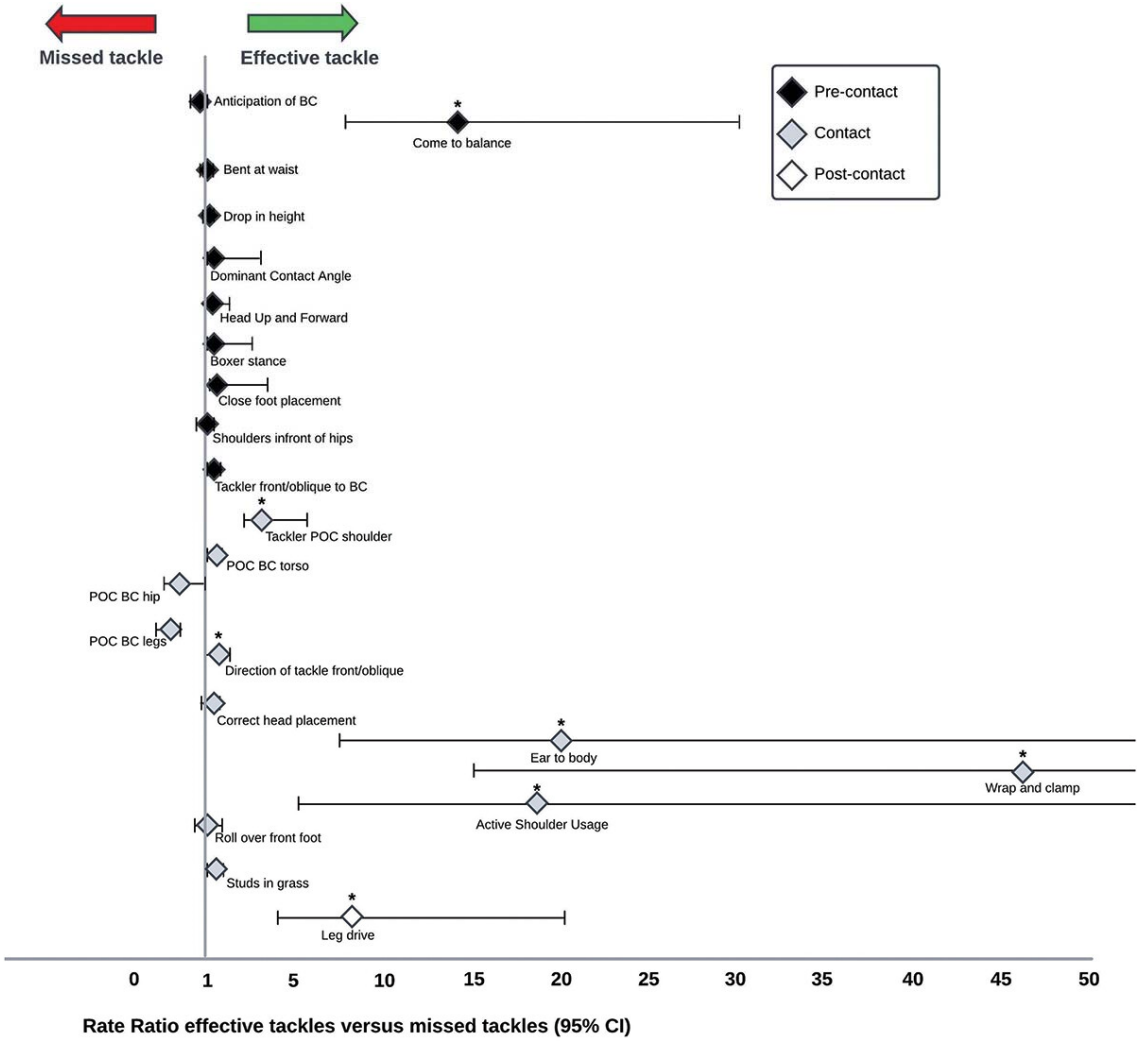

Figure 3. Summary of *Tackle Ready* techniques for missed tackles and tackle effectiveness (World Rugby, 2022a). Data reported as rate ratio (RR) and 95% confidence intervals (95% CI). RR > 1 indicates a greater likelihood of effective tackles and RR < 1 indicates a greater likelihood of missed tackles. (BC ball-carrier) asterisk denotes

statistically significant Bonferroni-corrected *p* values (p < 0.000694). note: upper CI limits for ear to body (95% CI 7.05–102), wrap and clamp (95% CI 15.9–228), and active shoulder usage (95% CI 5.03–155) have been cut off.

Tackle ready tackler techniques and tackle performance

All three phases of the tackle had *Tackle Ready* characteristics that increased the likelihood of effective tackle performance outcomes (Supplementary table 5) (Figure 3). Seven out of 22 coded *Tackle Ready* techniques demonstrated a significant association with superior tackle performance. During the pre-contact phase of tackling, the likelihood of effective tackles significantly increased when tacklers "come to balance" (RR 14.5, 7.57–31.9, *p* = 0.00, ES=moderate), or approached "front/oblique to ball-carrier" (RR 1.36, 95% CI 1.06–1.77, *p* = 0.01, ES=small). When the tackler demonstrated "head up and forward" pre-contact postures (RR 1.59, 95% CI 1.19–2.14, *p* = 0.00, ES=small), the chance of an effective tackle increased.

In the contact phase, the likelihood of an effective tackle significantly increased when the tackler made contact with their shoulder (RR 3.39, 95% CI 2.17–5.57, *p* = 0.00, ES=small) to the ball-carrier's torso (RR 1.44, 95% CI 1.04–2.03, *p* = 0.02, ES=small) and/or wrapped and clamped the ball-carrier (RR 46.8, 95% CI 15.9–227.6, *p* = 0.00, ES=moderate). "Active shoulder usage" (RR 18.5, 95% CI 5.03–154.6, *p* = 0.00, ES=small) and maintaining ear to ball-carrier contact (RR 20.9, 95% CI 7.05–102.0, *p* = 0.00, ES=small) also significantly increased the likelihood of effective tackles. Contact to the leg of the ball-carrier significantly increased the likelihood of missed tackles (RR 0.48, 95% CI 0.31–0.76, *p* = 0.00, ES=small).

In the post-contact phase, "strong tackler leg drive" (RR 8.62, 95% CI 4.31–20.2, *p* = 0.00, ES=small) significantly increased the likelihood of effective tackles when compared to missed tackles.

The propensity for effective tackles versus missed tackles is greatest for moderate-speed tackles (RR: 1.31, 95% CI 1.02–1.22), *p* = 0.03). Tackles with proximity to the ball-carrier's torso resulted in the highest propensity for effective tackles versus missed tackles (RR 1.44, 95% CI 1.04-2.03, p=0.02, ES=small) (Figure 4). As the point of contact on the ball-carrier lowered from the proximity of the torso to the hip to the leg, the propensity for effective tackles decreased.

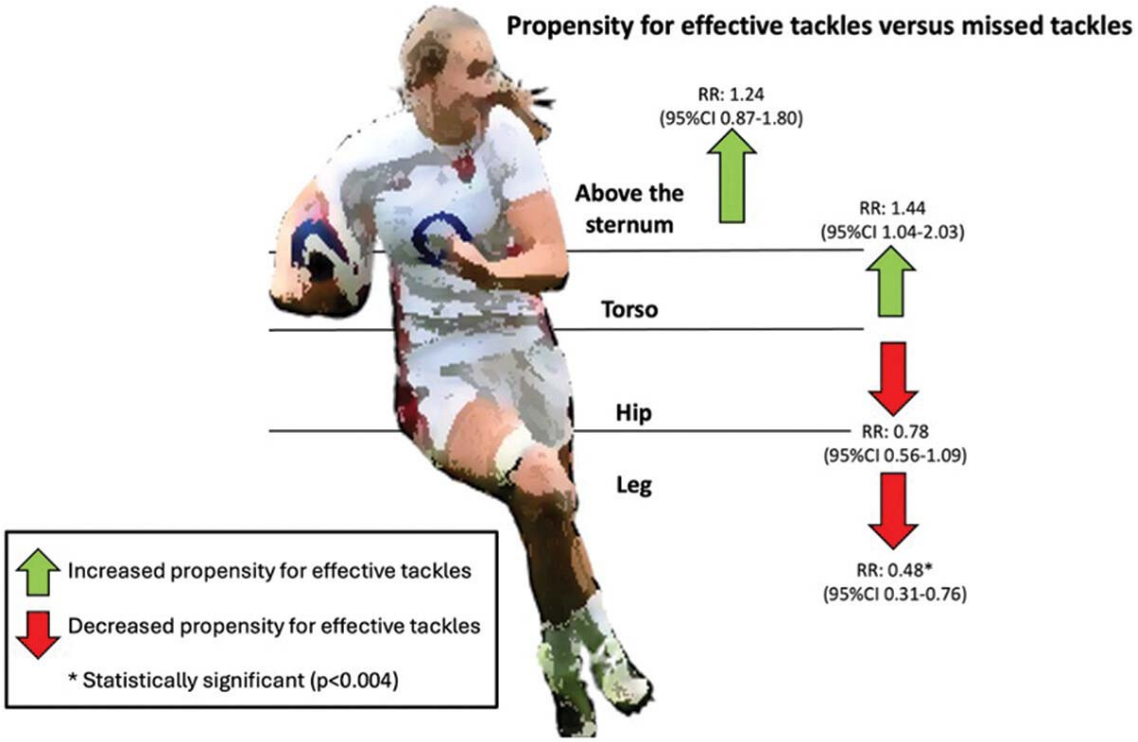

Figure 4. The rate ratios and 95% confidence intervals for effective tackles versus missed tackles for the intial point of contact on ball-carrier. Bonferroni corrected *p* values ($p < 0.004$).

Discussion

The present study is the first to identify the tackle technical characteristics and *Tackle Ready*-recommended tackler techniques associated with performance outcomes in elite women's rugby. Effective tackles were associated with match situations involving two defenders, defensive teams moving forwards and tackles initiated closer to attackers at ball reception. Ball-carrier fend, leg-drive and side-stepping at high speed increased the chances of missed tackles. Seven out of 22 coded *Tackle Ready* techniques demonstrated a significant association with superior tackle performance. As the point of contact on the ball-carrier lowered from the torso to the hip to the leg, the propensity for effective tackles decreased. Although further research is needed to assess associations with tackle-related injury prevention, this study provides useful information for stakeholders in women's rugby to support tackle coaching practice, education resources, and tackle height law changes.

Match situational characteristics

The tackler being less than two metres from the ball-carrier at ball reception reduced the ball-carriers' chances of breaking the tackle. This affords less time and space for the attackers to select and execute their play and provides further evidence in support of coaching defensive line speed. However, the propensity for effective tackles was greater when the tackler was travelling at low speed rather than high speed. For the skill of tackling, whilst increased speed can enhance a tackler's ability to close the gap quickly and increase pressure on the attacker, previous research in men's rugby has highlighted an increased risk of missed tackles (Hendricks et al., 2013) and concussion when tacklers move at high speed (Tucker et al., 2017). Speed also alters kinematics and kinetics in other movements such as change-of-direction tasks (Vanrenterghem et al., 2012). As well as mitigating momentum and the force of impact, lower speeds may afford tacklers time to react to a sudden ball-carrier change of direction. A

key focus of tackle coaching should be to ensure women are prepared to proficiently perform recommended techniques at different speeds and under fatigue (Davidow et al., 2023). In addition to improving tackle technical proficiency and capacity, developing neuromuscular (i.e., footwork, speed, and strength) and cognitive (i.e., decision-making) functions are crucial for skill learning and transfer to matches (Hendricks, Till, et al., 2018).

Defensive simultaneous or sequential tackles (2v1) were indicative of more effective tackles. The ability to coordinate and execute two-defender tackles is not only dependent on technical proficiency but also tactical proficiency (e.g., defensive speed, direction, shape) (Hendricks et al., 2013). Previous research in elite men's rugby (Tucker et al., 2017), and women's varsity rugby noted that three defender tackles increased the odds of tackler concussions (Shill et al., 2024). The frequency and risk of injury associated with multi-defender tackles underscores the importance of giving players consistent training exposures to these types of tackles. In contrast, the performance advantages of two-defender tackles may have implications on the implementation of future law-changes. For example, in the community game, Fédération Française de Rugby (FFR) has trialled law-changes to lower the height of a legal tackle to below the waist as well as prohibiting two-defender tackles (World Rugby, 2023). Given the frequency (48%) and performance advantages of two-defender tackles (RR 26.5), it may take time for the desired behavioural changes to fully manifest in the women's game (Hendricks et al., 2023).

Ball-carrier characteristics

Ball-carriers were more likely to break the tackle if they ran with upright body position, at high speed, using side-step, fend and leg drive after contact. This is comparable to effective attacking strategies in elite men's rugby union (den Hollander et al., 2021). An attacker using a fend and side-step to avoid contact is likely to put the defender in a weaker position; thus, the attacker may break the tackle or free their arms to offload the ball. To best prepare defenders for match demands, coaching emphasis could be placed on how to counteract the ball-carrier evasive footwork and fend (Hendricks et al., 2013, 2014, 2018).

Tackle ready characteristics

Seven out of 22 coded *Tackle Ready* techniques demonstrated a significant association with superior tackle performance. This may raise concerns about the practicality and efficacy of having over 22 recommended techniques for coaches and players to consider (World Rugby, 2022a). Although further research is needed to assess associations with injury prevention, a more focused and streamlined approach may be beneficial.

The results underpin the importance of coaching the pre-contact phase of the tackle with emphasis on coming to balance (RR 14.5), close tackler foot placement (RR 1.95), and boxer stance (RR 1.66) to aid defenders in preparing for contact. While "up and forward" head positioning (RR 1.59) was associated with effective tackle performance, only one in every two tackles demonstrated this (W:50% versus M:98%) (Burger et al., 2016; Hendricks, van Niekerk, et al., 2018). Head "up and forward" enables tacklers to keep eyes on the attacker and target correct head placement and contact on the ball-carrier. In elite male rugby, correct head positioning pre-contact reduced the likelihood of tackler Head Impact Assessments (HIA) (Tierney et al., 2018). Therefore, highlighting that safe tackle technique can reduce injury risks and improve performance. Although previously unexplored in men's rugby, tackler "come to balance" (RR 14.5) had a significant association with tackle performance in the present study. The *Tackle Ready* framework recommends defenders maintaining balance to allow for adjustment in footwork and body position to enable more balanced and powerful positioning prior to contact (World Rugby, 2022a).

Education resources should be evaluated to ensure they adequately assist women's rugby coaches in targeting these pre-contact techniques within training.

During the contact phase, "wrap and clamp" (RR 46.8), "ear to body" contact (RR 20.9), "active shoulder usage" (RR 18.5), "initial shoulder contact" (3.39), and front/oblique tackles (RR 1.30) were significantly associated with effective tackles. While using the arms to wrap around the ball-carrier is a fundamental and legal requirement when making a tackle, it also demands training attention and considerable upper body strength to execute effectively. As well as enhancing performance, ear-to-body contact might limit tackler head movement during the tackle, potentially reducing risks of head injury. A player's ability to maintain ear-to-body contact may rely on neck strength. Considering that the relative maximal isometric neck strength in female rugby players is reported to be 47% lower than in males (Williams et al., 2022), incorporating elements of World Rugby's *Contact Confident* education resource into tackle training plans could help facilitate this (World Rugby, 2022b). In accordance with men's rugby research, front-on/oblique tackles were associated with superior performance (den Hollander et al., 2021). However, the present study revealed that most tackles were made behind the ball-carrier (36%) or side-on to the ball-carrier (31%), potentially indicating deficiencies in defensive systems (e.g., positional mismatches or attacking overlaps) or the use of distinct defensive strategies by women. In men's rugby, there is a greater likelihood of HIA following front-on tackles (Tucker et al., 2017). While *Tackle Ready* recommendations encourage front/oblique tackles, tackle training should feature sufficient exposures to side-on and behind tackles to prepare players for match demands.

Contacting the torso of the ball-carrier (RR 1.44) was associated with superior tackle performance, limiting the attacker's ability to free her arms to offload the ball (den Hollander et al., 2021). World Rugby has introduced opt-in global trials to lower the maximum tackle height in community rugby from the line of the ball-carriers' shoulders to below the sternum to prevent head injury risk (World Rugby, 2023). In addition to potentially mitigating head injury risks (Tierney & Simms, 2018), findings from the present study demonstrate that tackles made above the sternum of the ball-carrier (n = 209, 14%) have a lower propensity for effective tackles compared to torso tackles. This offers evidence in support of law changes to lowering tackle height. However, law trials in the FFR are evaluating further lowering the height of the legal tackle from below armpit level to below waist level within community rugby (World Rugby, 2023). In the present study, contacting the legs of the ball-carrier increased the likelihood of offloads, passive and missed tackles. Therefore, this performance limitation may pose a challenge to player and coach buy-in (Dane, Foley, & Wilson, 2023; McKay & Verhagen, 2016; Vella et al., 2022), and it is likely that tackle coaching will have to innovate defensive strategies to counteract offloads. At present, generally it is the role of a second tackler (tackle assist) to stop offloads by contacting the torso of the ball-carrier. Strength and conditioning will need to be adapted to support a greater emphasis on lower body positions and increased physical demands of more frequent line breaks and offloads (e.g., locomotor and collision demands).

During the post-contact phase, tackler leg drive (RR 8.62) significantly increased the likelihood of superior performance. Only 29% (n = 435) of tackles demonstrated "tackler leg drive". This may be a result of interactions of preceding or simultaneous techniques. For instance, it might be more difficult for tacklers to generate leg drive from distant foot placement (79%, n = 1184) or from a more upright torso position (30%, n = 447). While more work is required to understand relationships amongst technique, fatigue, tactics and performance, coaches should consider these factors when implementing contact preparation in practice (Dane, Foley, Hendricks, et al., 2023; Hendricks, Till, et al., 2018).

Limitations

The limitations of the video analysis methods used in the present study have been described previously (Dane, West, Simms, et al., 2024). The application of this research to the community game remains unknown and further research is warranted across different age categories, competition levels and teams in southern hemisphere rugby contexts (McLeod et al., 2023; Shill et al., 2024). To facilitate more accurate gender-related comparisons, future research should evaluate the *Tackle Ready* recommended techniques associated with performance in elite men's Rugby. The study acknowledges the inability of mono-dimensional video-based analysis to accurately capture the complex physical, physiological, and psychological requisites of the live match-play. Only rate ratios and propensity rates were analysed in this study. Future research should include modelling of the combination and interaction between match situation, tackler and ball-carrier tackle characteristics. Given the multiple comparisons and assessment of tackle techniques separately, some effects will represent underlying relationships between the technical characteristics, whereby a change in one technique likely contributes to changes in others. Nonetheless, this work provides the foundation for similar women's rugby video analysis studies in the future and findings can be applied to optimise contact training.

Considerations for practice and future research

Although further research is needed to assess associations with injury prevention, considering that only 7 out of 22 coded techniques demonstrated a significant relationship with performance, there could be a case for more focused tackle coaching and tackle technique recommendations within education resources. As well as providing a framework of seven key techniques to prioritise during contact training and performance analysis, the results offer greater context for law changes and an opportunity to re-evaluate the content and communication of tackle safety programmes for improved adoption (Dane, Foley, & Wilson, 2023, 2024; McKay & Verhagen, 2016). Rugby performance is considered a "complex dynamical system" comprising inherently unpredictable and interacting components that guide a player's actions (Araújo et al., 2006; Passos et al., 2008). Match situations, preceding and/or simultaneous techniques might have a significant interaction with the execution of subsequent tackler techniques. Further analytical approaches (e.g., Random Forest Classification, principal component analysis, decision trees) are needed to explore these interactions in the future (Watson et al., 2021).

Conclusion

This was the first study to describe tackle technical characteristics associated with performance outcomes in elite women's rugby. Seven out of 22 coded *Tackle Ready* techniques demonstrated a significant association with effective tackle performance. While further analysis is needed to determine the interaction between match situations, tactical actions, techniques and what recommended techniques mitigate injury risk during tackling, there may be an opportunity to refine tackle technique recommendations and education resources. Rugby stakeholders can leverage the results presented to guide coaching practice, performance analysis, tackle safety education and the implementation of law changes.

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