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Original research

The effect of lowering the maximum tackle height in English Schoolboy rugby union on tackle characteristics and all-injury and concussion rates

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ABSTRACT

Objectives: This study compared tackle characteristics and injury incidence in schoolboy rugby union before and after a law change that lowered the maximum legal tackle height.
Design: Prospective cohort study.
Methods: Match injuries and game exposures were reported by U15 and U18 schoolboy teams over three seasons (2017/18 to 2019/20) when the legal tackle height was at the line of the shoulder and one season (2021/22) at the line of the armpit. Matches were filmed pre- (U15:11; U18:16 matches) and post- (U15:10; U18:10 matches) tackle height change and tackles were coded for tackler and ball carrier techniques. Tackle characteristic propensities and injury incidences were compared pre- and post-tackle height change using rate ratios (95 % confidence intervals).
Results: Pre- to post-tackle height change, the propensity of shoulder height tackles reduced at U15 (rate ratio: 0.62, 95 % confidence interval: 0.51–0.75) and U18 (rate ratio: 0.77, 95 % confidence interval: 0.65–0.92). Post-change, tacklers were more often bent at the waist when tackling at U15 (rate ratio: 1.34, 95 % confidence interval: 1.21–1.49) and U18 (rate ratio: 1.18, 95 % confidence interval: 1.08–1.29).
Overall injury incidence pre- and post-tackle height change was not significantly different for U15 (rate ratio: 0.79, 95 % confidence interval: 0.53–1.17) or U18 (rate ratio: 1.11, 95 % confidence interval: 0.89–1.37). Pre- to post-tackle height change, neither all concussions at U15 (rate ratio: 1.43, 95 % confidence interval: 0.73–2.70) and U18 (rate ratio: 0.95, 95 % confidence interval: 0.59–1.47) or tackle-related concussions at U15 (rate ratio: 1.39, 95 % confidence interval: 0.55–3.25) and U18 (rate ratio: 0.92, 95 % confidence interval: 0.48–1.65) were different.
Conclusions: Following a lowering of the permitted tackle height, tackler and ball carrier tackle techniques changed, without changing the incidence of all injuries or concussions. Further lowering of the tackle height may be explored to invoke the necessary technique changes to reduce injury.

Practical implications

- Following a law change in English youth rugby union to reduce the maximum permitted tackle height from the level of the shoulder to the armpit, there were changes to the tackler's technique.

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- Tackles made at the height of the ball carrier's shoulder were reduced and tacklers were more often bent at the waist at the point of entering the tackle. This resulted in more tackles that would be aligned with an effective technique in coaching practice.
- Following the law change, there were no changes in the incidence of all types of injury and specifically concussions.

1. Introduction

Rugby union is a collision team sport played by nearly eight million people around the world.[1] Player-to-player collisions and contact in the game create an inherent risk of injury, and in the boys' game, 24 hour time-loss match injury incidences of 40.2/1000 h [95 % confidence intervals (CIs): 13.9–66.5] have been reported.[2] In the English schoolboy game, injury incidence in Under 18s (U18; 34.6/1000 h; 95 % CI: 31.5–38.1) appears to be greater than in Under 15s (U15; 24.6/1000 h; 95 % CI: 20.6–29.5).[3] Concussion is consistently identified as one of the most common match injury diagnoses across male[2,3] and female[2] youth and men's professional[4] levels of rugby. In boys' rugby, reported concussion rates are 6.2/1000 h (95 % CIs: 5.0–7.4), representing 17 % of all injuries.[2] Injuries are most commonly associated with the tackle, which accounts for 55 % of all injuries and 76 % of all concussions in boys' rugby.[2]

The characteristics of tackles that result in head impacts and concussion have been studied in elite men's rugby. Tackler acceleration, tackler speed, head-to-head contact and high tackles are all associated with a greater likelihood of a concussion[5] or head injury assessment[6] occurring. The authors of these observational studies[5,6] identified lowering the tackle height as an approach to modify player body position and reduce concussion risk. As such, two studies[7,8] have been conducted in rugby union to compare all injury and concussion outcomes when the legal height of the tackle was reduced from the level of the shoulder to the level of the armpit. In English men's elite-level rugby union,[7] this lower legal tackle height resulted in a lower proportion of tackles in which the ball carrier was upright and where the tackler's initial contact was to the ball carrier's head or neck. However, there was no reduction in overall injury and concussion incidence rates and increased tackler concussion incidence. In South African men's amateur rugby union,[8] there was no significant effect in all injury or concussion incidence. Both studies were conducted with adult players and no studies have yet assessed tackle law changes in youth rugby.

Until the 2020/21 season in the English age grade game, the maximum height of the legal tackle was the line of the armpit for age groups up to U14, and the line of the shoulder for U15 to U18 age groups. For the 2021/22 season, the national governing body for rugby in England (Rugby Football Union) made the maximum height of the legal tackle the armpit for all age groups up to U18. The purpose of this study was to compare boys' U15 and U18 tackle characteristics and time-loss injury and concussion rates between seasons 2017–20, in which the line of the shoulder was the maximum permitted tackle height, and the 2021/22 season, in which the line of the armpit was the maximum permitted tackle height.

2. Methods

2.1. Recruitment and participants

This prospective cohort study was conducted over four rugby seasons, the first three of which (2017/18, 2018/19, 2019/20) permitted the legal tackle height to be the line of the ball carrier's shoulder. For the fourth season (2021/22; no youth rugby was played in England in the 2020/21 season due to the COVID19 pandemic), the national governing body introduced a law change to all schools' rugby which reduced the permitted tackle height to the line of the ball carrier's armpit. Each season ran from September to April, with the majority of school matches being played between September and December. Schools were invited to participate for each separate season of the study from an existing database, comprising contact details for private (fee paying) and publicly funded schools across a range of playing levels. The number of schools invited was 85, 164, 278 and 287 in the first, second, third and fourth seasons, respectively, with only boys' teams in the U15 and U18 age groups being eligible for inclusion. All participating schools received the same standardised notification on the tackle height change as part of a national dissemination to all schools' and clubs' coaches in England. Study information sheets and consent forms were sent electronically to the nominated project co-ordinator at each school who obtained player assents and parental/guardian consents. Ethical approval was obtained from the institution's research ethics committee.

2.2. Variables

Methods were in accordance with the consensus statement on injury definitions and data collection procedures for studies of injury in rugby union,[9] as well as the 2020 IOC consensus on injury surveillance in sport[10] and have been described previously in this setting.[3] A 24-hour time-loss injury definition was used, where injuries were recorded if a player was unable to take a full part in training or match play for more than 24 h from midnight at the end of the day that the injury was sustained. Match exposure was determined as the number of games each participating team played over the season and was calculated by multiplying the duration of the match (h) by the number of players (15 per team). U15 games lasted 60 min and U18 games lasted 70 min.

2.3. Data collection

A nominated project co-ordinator at each school, normally a coach or medical practitioner (school nurse, sports therapist, physiotherapist), collected information using a bespoke worksheet which included drop-down lists in data entry fields. Prior to data collection, this person was contacted by the research team and instructed how to enter data relating to the team (age group), their matches (date, match duration) and match injuries (date, return to play date, match quarter, playing position, match event associated with the injury, body site, and suspected concussions as determined by the school's medical practitioner). Injury data was returned via a secure electronic link to the research team, who provided feedback to the project co-ordinator and requested verification for any injury data in the event of incomplete data fields.

2.4. Tackle analysis

Match footage was obtained from a sample of home matches for schools (Table 1) who contributed to the injury data collection during the 2018/19 (pre-tackle height change) and 2021/22 (post-tackle height change) seasons. The number of matches filmed was based on a convenience sample which was limited to camera operator availability and distributed between September and February. Matches were filmed using a single camera placed as close as possible to the half-way line with an elevated height of approximately 9 m above the ground, achieved through specialist portable equipment (Hi-pod, Los Angeles, USA). Camera operators were instructed to track the ball carrier throughout the game and to zoom into contact events. Match footage

Table 1
Number of matches filmed (percentage of the total matches used in injury exposure) and different teams involved for U15 and U18, pre- and post-law change.

Age group	Pre-law change		Post-law change	
	Number of matches/teams			
	Matches (%)	Teams	Matches (%)	Teams
U15	11 (3)	16	10 (9)	18
U18	16 (2)	21	10 (9)	16

was transferred to sports performance analysis software (Nacsport Pro Plus, V 6.5.0, Nacsport, Spain). Tackle events were identified and analysed using a bespoke coding window to characterise the first point of contact of the tackler on the ball carrier, tackler and ball carrier body positions, number of tacklers, tackle style (active, passive, smother, tap, unknown), direction of impact, tackler and ball carrier average speed into the tackle, and initial head contact for both the tackler and ball carrier. Where a tackle event was obscured or unclear, a variable was coded as 'unknown'. All coding descriptors were based on the consensus on video analysis in rugby union[11] with some amendments to definitions (Supplementary Table 1). Two coders completed all tackle analysis (MH pre-law change only and JP pre- and post-law change). Each coder underwent standardised training to identify and accurately code tackle characteristics and was required to successfully achieve inter-rater reliability of 90 % agreement for each characteristic with an expert coder (external to the author team) with over ten years' experience as a rugby analyst. The two coders undertook an inter-rater reliability, achieving a Cohen's kappa score across all variables of 0.8. Intra-rater reliability was assessed by coders one and two both completing a second coding assessment one month after the first, with respective Cohen's kappa scores of 0.91 and 0.90.

2.5. Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting, or dissemination plans of this research.

2.6. Equity, diversity, and inclusion

Our authorship team consisted of three women and eight men with experience ranging from early career researchers through to experienced principal investigators. Whilst both state-funded and private schools were invited to participate, most schools volunteering to take part were private schools, largely due to having more personnel available to record data for the study. This study only investigated the boys' game due to limited rugby match play for girls' teams in the school setting. There are ongoing trials in the 2023/24 season to assess the effectiveness of a reduced tackle height in the girls' game.

2.7. Statistical analysis

Descriptive analysis of tackle characteristics was undertaken to outline the number and proportion of each tackle characteristic observed within the sample. The propensity of each tackle characteristic was calculated per 1000 tackle events with corresponding 95 % confidence intervals (CIs). Propensities of tackle characteristics and injury incidence pre- and post-tackle height change were then compared using rate ratios (RRs) with corresponding 95 % CIs. Injury incidence was calculated using a Poisson regression model as the number of injuries per 1000 player match hours (injuries/1000 h) with 95 % CIs. Normality of data was assessed visually using histograms, as well as assessments of skewness and kurtosis. Non-normally distributed severity data was reported as median with inter-quartile range and means with 95 % confidence intervals, whilst all other normally distributed data was presented as means with 95 % confidence intervals. Statistical significance was established using an a-priori alpha level of 0.05 and a subsequent Holm–Bonferroni correction[11,12] was applied to account for multiple comparisons with adjusted alpha levels reported in results tables. Analysis of injury outcomes was undertaken for all injury types, with specific focus on concussions, all head/neck injuries, tackle-related injuries, and tackle-related concussions.

3. Results

In total, 1105 players from 36 schools (27 private schools and nine state schools) participated in the study over the four seasons (16 schools: one season, nine schools: two seasons, five schools: three seasons, five schools: four seasons).

3.1. Tackle analysis

In total, 9035 tackles (primary tackler only) were coded for characteristics. This included 2000 (from 11 different games) and 1936 (10 games) tackles in U15s pre- and post-law change, respectively, and 2779 (16 games) and 2320 (10 games) in U18s.

The U18 group saw a post-law change increase in one-person tackles [rate ratio, 1.20 (1.12–1.27)] and reductions in all other counts of tacklers (Table 3) but no changes were observed for the U15 group. Both age groups saw a significant increase in the rate of smother tackles [U15: RR, 2.97 (2.36–3.75); U18: RR, 2.72 (2.20–3.38)] and front-on tackles [U15: RR, 1.54 (1.33–1.79); U18: RR, 1.40 (1.25–1.57)].

There was no change to the propensity of tackles directly to the head/neck area [U15: RR, 1.00 (0.67–1.48); U18: RR, 0.98 (0.72–1.33)]. Point estimates demonstrated a significant reduction in the propensity of tackles to the shoulder and armpit post-law change at U15 [RR, 0.62 (0.51–0.75)] and U18 [RR, 0.77 (0.65–0.92)].

Similarly, for U15 post-law change, there was a significantly greater propensity of tackles to the upper leg [RR, 1.24 (1.09–1.43)] but there was no change in the lower leg [RR, 1.46 (1.03–2.10)]. Nonetheless, there was a significantly higher propensity of tacklers being "bent at the waist" [U15: RR, 1.34 (1.21–1.49); U18: RR, 1.18 (1.08–1.29)] post-law change, as well as more upright ball carriers at U18 [RR, 1.11 (1.05–1.19)] and fewer "bent at the waist" ball carriers at U15 [RR, 0.75 (0.61–0.91)]. There was no significant increase in the propensity of tackles in which the tackler was bent at the waist and the ball was upright for U15 [RR, 1.10 (0.98–1.24)] and U18 [RR, 1.10 (0.99–1.21)] but there was a lower propensity of U18 tackles where the tackler and the ball carrier were both bent at the waist [RR, 0.79 (0.67–0.94)] (Table 4). Finally, there was an increase in the number of "static" tacklers post-law change in both age groups [U15: RR, 1.23 (1.13–1.34); U18: RR, 1.46 (1.36–1.58)] (Tables 2 and 3). For U15, there was no difference in the propensity for referee-sanctioned penalisations but for U18, there was a significant post-law change reduction in penalisations [RR, 0.18 (0.08–0.34)].

3.2. Injury incidence and severity

A total of 692 match injuries were recorded; 153 in U15 matches and 539 in U18 matches over a total of 21,837 match hours (U15: 6575 h; U18: 15,262 h). Injury incidence rates were higher in the U18 group compared with the U15 group both pre-law change and post-law change across all outcome measures (Fig. 1, Supplementary Table 6). For both age groups, there were no significant differences pre- and post-law change for the incidence of all injuries combined (U15: RR, 0.79, 95 % CI: 0.53–1.17, $p = 0.27$; U18: RR, 1.11, 95 % CI: 0.89–1.37, $p = 0.34$), concussions (U15: RR, 1.43, 95 % CI: 0.73–2.70, $p = 0.31$; U18: RR, 0.95, 95 % CI: 0.59–1.47, $p = 0.82$), injuries to the head/neck, tackle injuries or tackle-related concussion (Fig. 1, Supplementary Table 6) for either the U15 or U18 age group. Further, no significant differences were seen in injury severity (mean days absence) pre- to post-law change in either U15 (pre: 24 days absence, 95 % CI: 20–29 vs post: 28, 95 % CI: 21–34) or U18 (pre: 27 days absence, 95 % CI: 25–30 vs post: 30, 95 % CI: 23–37) (Supplementary Table 6).

4. Discussion

The aim of this study was to determine whether lowering the maximum legal height of the tackle in U15 and U18 schoolboy rugby union match play from the line of the shoulder to the line of the armpit resulted in changes in tackle techniques and/or injury rates. Following the law change, there was evidence of a change in tackle technique with more tacklers entering the tackle bent at the waist and reductions in tackles made at the height of the ball carrier's shoulder in both age

Table 2
Rate ratios comparing tackle characteristics pre- and post-law change for U15. Rate ratios are calculated based on propensity rates per 1000 tackles.

		U15							
		Pre-law change			Post-law change			Rate ratio (95 % CI)	*p*-Value
		n = 2000	Proportion of all tackles	Propensity/1000 tackle events (95 % CI)	n = 1936	Proportion of all tackles	Propensity/1000 tackle events (95 % CI)		
No. of tacklers	1	1664	83	832.0 (796.3–869.3)	1695	88	876.0 (837.8–915.9)	1.05 (0.98–1.13)	0.14
	2	259	13	129.5 (123.8–135.3)	207	11	107.0 (102.3–111.9)	0.83 (0.68–1.00)	0.04
	3 +	17	1	8.5 (8.1–8.9)	9	0	4.7 (4.4–4.9)	0.55 (0.21–1.30)	0.14
	Unknown	60	3	30.0 (28.7–31.3)	24	1	12.4 (11.9–13.0)	**0.41 (0.25–0.67)**	**0.001**
Style	Active	269	13	134.5 (128.7–140.5)	215	11	111.1 (106.3–116.2)	0.83 (0.69–1.00)	0.04
	Passive	1186	59	593.0 (567.6–619.6)	1085	56	560.7 (536.3–586.3)	0.95 (0.87–1.03)	0.18
	Smother	104	5	52.0 (49.8–54.3)	299	15	154.5 (147.8–16.2)	**2.97 (2.36–3.75)**	**0.0001**
	Tap	30	2	15.0 (14.4–15.7)	30	2	15.5 (14.8–16.2)	1.03 (0.60–1.77)	0.90
	Unknown	411	21	205.5 (196.7–214.7)	306	16	158.1 (151.2–165.3)	**0.77 (0.66–0.89)**	**0.0005**
Direction	Front	307	15	153.5 (146.9–160.4)	458	24	236.7 (226.4–247.5)	**1.54 (1.33–1.79)**	**<0.0001**
	Side	1501	75	750.5 (718.3–784.1)	1291	67	667.2 (638.1–697.6)	**0.89 (0.82–0.96)**	**0.002**
	Back	114	6	57.0 (54.6–59.6)	140	7	72.4 (69.2–75.6)	1.27 (0.98–1.64)	0.06
	Unknown	78	4	39.0 (37.3–40.7)	46	2	23.8 (22.7–24.9)	0.61 (0.41–0.89)	0.007
Tackler's first point of contact on ball carrier	Head/neck	55	3	27.5 (20.7–35.7)	53	3	27.3 (20.5–35.8)	1.00 (0.67–1.48)	0.98
	Shoulder and armpit	281	14	140.5 (124.6–157.9)	168	9	86.8 (74.2–100.9)	**0.62 (0.51–0.75)**	**<0.0001**
	Torso	909	45	454.5 (425.4–485.0)	864	45	446.3 (417.0–477.1)	0.98 (0.89–1.08)	0.70
	Upper leg	394	20	197.0 (178.0–217.4)	476	25	245.9 (224.3–269.0)	**1.24 (1.09–1.43)**	**0.001**
	Lower leg	57	3	28.5 (21.6–36.9)	81	4	41.8 (33.2–52.0)	1.46 (1.03–2.10)	0.03
	Unknown	304	15	152.0 (135.4–170.0)	294	15	151.9 (135.0–170.2)	0.99 (0.85–1.18)	0.99
Tackler body position	Upright	882	44	441.0 (412.4–471.1)	740	38	382.2 (355.2–410.8)	0.87 (0.78–0.96)	0.004
	Bent	634	32	317.0 (292.8–342.7)	825	43	426.1 (397.5–456.2)	**1.34 (1.21–1.49)**	**<0.0001**
	Diving	386	19	193.0 (174.2–213.2)	324	17	167.4 (149.6–186.6)	0.87 (0.75–1.01)	0.06
	Unknown	98	5	49.0 (39.8–59.7)	47	2	24.3 (17.8–32.2)	**0.49 (0.34–0.71)**	**<0.0001**
Ball carrier body position	Upright	1622	81	811.0 (772.0–851.5)	1671	86	863.1 (822.2–905.5)	1.06 (0.99–1.14)	0.07
	Bent	256	13	128 (113.0–144.7)	185	10	95.6 (82.2–110.4)	**0.75 (0.61–0.91)**	**0.002**
	Diving	24	1	12.0 (7.6–17.9)	33	2	17.0 (11.7–23.9)	1.42 (0.81–2.51)	0.19
	Unknown	98	5	49.0 (39.8–59.7)	47	2	24.2 (17.8–32.2)	**0.49 (0.34–0.71)**	**<0.0001**

(continued on next page)

Table 2 (*continued*)

		U15							
		Pre-law change			Post-law change			Rate ratio (95 % CI)	*p*-Value
		n = 2000	Proportion of all tackles	Propensity/1000 tackle events (95 % CI)	n = 1936	Proportion of all tackles	Propensity/1000 tackle events (95 % CI)		
Penalisation	All	13	1	6.5 (3.5–11.1)	15	1	7.7 (4.3–12.8)	1.19 (0.53–2.72)	0.65
	FPOC[a]_Head/neck	8	<1	4.0 (1.7–7.9)	13	1	6.7 (3.6–11.5)	1.68 (0.64–4.67)	0.25
	FPOC[a]_Other site	5	<1	2.5 (0.8–5.8)	2	<1	1.0 (0.1–3.7)	0.41 (0.04–2.52)	0.31
Ball carrier's initial head contact on	Ground	64	3	32.0 (24.6–40.9)	44	2	22.7 (16.5–30.5)	0.71 (0.47–1.06)	0.08
	Equipment	1	<1	0.5 (0.1–2.7)	0	0	0	NA	NA
	Lower leg	0	0	0	0	0	0	NA	NA
	Knee	0	0	0	0	0	0	NA	NA
	Upper leg	0	0	0	0	0	0	NA	NA
	Hip	0	0	0	0	0	0	NA	NA
	Torso	14	1	7.0 (3.8–11.7)	10	1	5.2 (2.5–9.5)	0.74 (0.29–1.79)	0.47
	Shoulder	74	4	37.0 (29.1–46.5)	74	4	38.2 (30.0–48.0)	1.03 (0.74–1.45)	0.84
	Arm	54	3	27.0 (20.2–35.2)	35	2	18.1 (12.6–25.1)	0.67 (0.42–1.04)	0.06
	Head	37	2	18.5 (13.0–25.5)	51	3	26.3 (19.6–34.6)	1.42 (0.91–2.24)	0.10
	Other player	85	4	42.5 (33.9–52.6)	67	3	34.6 (26.8–44.0)	0.81 (0.58–1.13)	0.21
	Unknown	397	20	198.5 (179.5–219.0)	240	12	124.0 (108.8–140.7)	**0.62 (0.53–0.73)**	**<0.0001**
	None	1274	64	637.0 (602.5–673.0)	1414	73	730.4 (692.8–769.5)	1.15 (1.06–1.23)	0.004
Tackler's initial head contact on	Ground	10	1	5.0 (2.4–9.2)	4	<1	2.1 (0.6–5.3)	0.41 (0.09–1.43)	0.13
	Equipment	0	0	0	0	0	0	NA	
	Lower leg	35	2	17.5 (12.1–24.3)	47	2	24.3 (17.8–32.2)	1.39 (0.88–2.21)	0.14
	Knee	2	0	1.0 (0.1–3.6)	6	<1	3.1 (1.1–6.7)	3.10 (0.55–31.4)	0.17
	Upper leg	149	7	74.5 (63.0–87.5)	57	3	29.4 (22.2–38.1)	**0.40 (0.29–0.54)**	**<0.0001**
	Hip	141	7	70.5 (59.3–83.1)	337	17	174.1 (156.0–193.7)	**2.47 (2.02–3.03)**	**<0.0001**
	Torso	343	17	171.5 (153.8–190.6)	421	22	217.5 (197.2–239.3)	**1.27 (1.10–1.47)**	**0.001**
	Shoulder	114	6	57.0 (47.0–68.7)	126	7	65.1 (54.2–77.5)	1.14 (0.88–1.48)	0.31
	Arm	24	1	12.0 (7.6–17.9)	10	1	5.2 (2.5–9.5)	0.43 (0.18–0.93)	0.02
	Head	36	2	18.0 (12.6–24.9)	10	1	5.3 (2.5–9.5)	**0.29 (0.13–0.59)**	**0.002**
	Other player	4	<1	2.0 (0.5–5.1)	2	<1	1.0 (0.1–3.7)	0.52 (0.47–3.60)	0.48
	Unknown	389	19	194.5 (175.6–214.8)	258	13	133.3 (117.5–150.6)	**0.69 (0.58–0.80)**	**<0.0001**
	None	753	38	376.5 (350.1–404.4)	611	32	315.6 (291.1–341.6)	**0.84 (0.75–0.93)**	**0.001**
Tackler speed	Static	1014	51	507.0 (476.3–539.2)	1211	63	625.5 (590.7–661.8)	**1.23 (1.13–1.34)**	**<0.0001**
	In motion	793	40	396.5 (369.4–425.1)	588	30	303.7 (279.7–329.3)	**0.77 (0.69–0.85)**	**<0.0001**
	High speed	121	6	60.5 (50.2–72.3)	108	6	55.8 (45.8–67.4)	0.92 (0.70–1.21)	0.54
	Unknown	72	4	36.0 (28.2–45.3)	29	1	15.0 (10.0–21.5)	**0.42 (0.26–0.65)**	**<0.0001**
Carrier speed	Static	233	12	116.5 (102.0–132.5)	233	12	120.4 (105.4–136.8)	1.03 (0.86–1.24)	0.73
	In motion	1449	72	724.5 (687.7–762.8)	1329	69	686.5 (650.1–724.4)	0.95 (0.88–1.02)	0.16
	High speed	246	12	123.0 (108.1–139.4)	345	18	178.2 (159.9–198.0)	**1.45 (1.23–1.71)**	**<0.0001**
	Unknown	72	4	36.0 (28.2–45.3)	29	1	15.0 (10.0–21.5)	**0.42 (0.26–0.65)**	**<0.0001**

Adjusted alpha: <0.002.

[a] FPOC: First point of contact.

Table 3
Rate ratios comparing tackle characteristics pre- and post-law change for U18. Rate ratios are calculated based on propensity rates per 1000 tackles.

		U18							
		Pre-law change			Post-law change			Rate ratio (95 % CI)	*p*-Value
		N = 2779	Proportion of all tackles	Propensity/1000 tackle event (95 % CI)	N = 2320	Proportion of all tackles	Propensity/1000 tackle events (95 % CI)		
No. of tacklers	1	2014	72	724.7 (698.3–752.2)	2012	87	867.2 (832.7–903.3)	**1.20 (1.12–1.27)**	**<0.0001**
	2	605	22	217.7 (209.8–226.0)	263	11	113.4 (108.8–118.1)	**0.52 (0.45–0.60)**	**<0.0001**
	3+	57	2	20.5 (19.8–21.3)	12	1	5.2 (5.0–5.4)	**0.25 (0.12–0.48)**	**<0.0001**
	Unknown	103	4	37.1 (35.7–38.5)	33	1	14.2 (13.7–14.8)	**0.38 (0.25–0.57)**	**<0.0001**
Style	Active	434	16	156.2 (150.5–162.1)	341	15	147.0 (141.1–153.1)	0.94 (0.81–1.09)	0.40
	Passive	1891	68	680.5 (655.6–706.2)	1387	60	597.8 (574.0–622.7)	**0.88 (0.82–0.94)**	**0.002**
	Smother	128	5	46.1 (44.4–47.8)	291	13	125.4 (120.4–130.6)	**2.72 (2.20–3.38)**	**<0.0001**
	Tap	40	1	14.4 (13.9–14.9)	39	2	16.8 (16.1–17.5)	1.17 (0.73–1.86)	0.49
	Unknown	286	10	102.9 (99.2–106.8)	262	11	112.9 (108.4–117.6)	1.10 (0.92–1.30)	0.28
Direction	Front	555	20	199.7 (192.4–207.3)	649	28	279.7 (268.6–291.4)	**1.40 (1.25–1.57)**	**<0.0001**
	Side	1855	67	667.5 (643.1–692.8)	1440	62	620.7 (595.9–646.5)	0.93 (0.87–1.00)	0.04
	Back	201	7	72.3 (69.7–75.1)	165	7	71.1 (68.3–74.1)	0.98 (0.80–1.21)	0.87
	Unknown	168	6	60.5 (58.2–62.7)	66	3	28.4 (27.3–29.6)	**0.47 (0.35–0.63)**	**<0.0001**
Tackler's first point of contact on ball carrier	H/N	100	4	36.0 (29.3–43.8)	82	4	35.3 (28.1–43.9)	0.98 (0.72–1.33)	0.91
	Shoulder to armpit	345	12	124.1 (111.4–138.0)	223	10	96.1 (83.9–109.6)	**0.77 (0.65–0.92)**	**0.003**
	Torso	1196	43	430.4 (406.3–455.5)	1039	45	447.8 (421.0–475.9)	1.04 (0.96–1.13)	0.35
	Upper leg	598	22	215.2 (198.3–233.1)	538	23	231.9 (212.7–252.3)	1.08 (0.96–1.21)	0.21
	Lower leg	112	4	40.3 (33.2–48.5)	103	4	44.4 (26.2–53.8)	1.10 (0.84–1.44)	0.48
	Unknown	428	15	154.0 (139.8–169.3)	335	14	144.4 (129.3–160.7)	0.94 (0.81–1.08)	0.38
Tackler body position	Upright	918	33	330.0 (309.3–352.4)	749	32	322.8 (300.1–346.8)	0.98 (0.89–1.08)	0.64
	Bent	1076	39	387.2 (364.4–411.0)	1060	46	456.9 (429.9–485.3)	**1.18 (1.08–1.29)**	**0.0001**
	Diving	614	22	220.9 (203.8–239.1)	446	19	192.2 (174.8–210.9)	0.87 (0.77–0.98)	0.03
	Unknown	171	6	61.5 (52.7–71.5)	65	3	28.0 (21.6–35.7)	**0.46 (0.34–0.61)**	**<0.0001**
Ball carrier body position	Upright	2045	74	735.9 (704.3–768.5)	1903	82	820.2 (783.8–858.0)	**1.11 (1.05–1.19)**	**<0.0001**
	Bent	507	18	182.4 (166.9–199.0)	317	14	136.4 (122.0–152.5)	0.88 (0.76–1.00)	0.05
	Diving	56	2	20.2 (15.2–26.2)	35	2	15.1 (10.5–21.0)	0.75 (0.48–1.16)	0.18
	Unknown	171	6	61.5 (52.7–71.5)	65	3	28.0 (21.6–35.7)	**0.46 (0.34–0.61)**	**<0.0001**

(continued on next page)

Table 3 (*continued*)

		U18							
		Pre-law change			Post-law change			Rate ratio (95 % CI)	*p*-Value
		N = 2779	Proportion of all tackles	Propensity/1000 tackle event (95 % CI)	N = 2320	Proportion of all tackles	Propensity/1000 tackle events (95 % CI)		
Penalisation	All	68	2	24.5 (19.0–31.0)	10	<1	4.3 (2.1–7.9)	**0.18 (0.08–0.34)**	**<0.0001**
	FPOC[a]_Head/neck	15	1	5.4 (3.0–8.9)	6	<1	2.6 (0.9–5.6)	0.48 (0.15–1.31)	0.12
	FPOC[a]_Other site	53	2	19.1 (14.3–24.9)	4	<1	1.7 (0.5–4.4)	**0.09 (0.02–0.25)**	**<0.0001**
Ball carrier's initial head contact on	Ground	120	4	43.2 (35.8–51.6)	67	3	28.9 (22.4–36.7)	0.67 (0.49–0.91)	0.007
	Equipment	2	<1	0.7 (0.1–2.6)	0	0	NA	NA	
	Lower leg	0	0	NA	0	0	NA	NA	
	Knee	1	<1	0.4 (0.01–2.0)	0	0	NA	NA	
	Upper leg	0	0	NA	1	<1	0.4 (0.01–2.4)	NA	
	Hip	3	<1	1.1 (0.2–3.2)	2	<1	0.9 (0.1–3.1)	0.80 (0.07–6.97)	0.83
	Torso	44	2	15.8 (11.5–21.3)	22	1	9.4 (5.9–14.3)	0.60 (0.34–1.02)	0.05
	Shoulder	96	3	34.5 (28.0–42.2)	125	5	53.9 (44.8–64.2)	**1.56 (1.19–2.06)**	**0.001**
	Arm	78	3	28.1 (22.2–35.0)	42	2	18.1 (13.0–24.5)	0.64 (0.43–0.95)	0.02
	Head	66	2	23.7 (18.5–30.2)	47	2	20.3 (14.9–26.9)	0.85 (0.57–1.26)	0.41
	Other player	189	7	68.0 (58.7–78.4)	113	5	48.7 (40.1–58.6)	0.72 (0.56–0.91)	0.005
	Unknown	674	24	242.5 (224.6–261.6)	378	16	162.9 (146.9–180.2)	**0.67 (0.59–0.76)**	**<0.0001**
	None	1506	54	541.9 (514.9–570.0)	1523		656.5 (623.9–690.3)	**1.21 (1.13–1.30)**	**<0.0001**
Tackler's initial head contact on	Ground	18	1	6.5 (3.8–10.2)	1	<1	0.4 (0.01–2.4)	**0.07 (0.02–0.42)**	**0.0002**
	Equipment	0	0	NA	0	0	NA	NA	
	Lower leg	59	2	21.2 (16.2–27.4)	53	2	22.8 (12.1–29.9)	1.08 (0.73–1.59)	0.70
	Knee	29	1	10.4 (6.9–15.0)	12	1	5.2 (2.7–9.0)	0.50 (0.23–1.00)	0.04
	Upper leg	128	5	46.1 (38.4–54.8)	92	4	39.7 (32.0–48.6)	0.86 (0.65–1.13)	0.27
	Hip	298	11	107.2 (95.4–120.1)	371	16	159.9 (144.1–177.0)	**1.49 (1.28–1.74)**	**<0.0001**
	Torso	345	12	124.1 (111.4–138.0)	573	25	247.0 (227.2–268.1)	**1.98 (1.74–2.28)**	**<0.0001**
	Shoulder	152	5	54.7 (46.3–64.1)	183	8	78.9 (67.9–91.2)	**1.44 (1.16–1.80)**	**0.0008**
	Arm	84	3	30.2 (24.1–37.4)	17	1	7.3 (4.3–11.7)	**0.24 (0.13–0.41)**	**<0.0001**
	Head	67	2	24.1 (8.7–30.6)	48	2	20.7 (15.3–27.4)	0.86 (0.58–1.26)	0.42
	Other player	12	<1	4.3 (2.2–7.5)	6	<1	2.6 (0.9–5.6)	0.60 (0.18–1.72)	0.31
	Unknown	746	27	268.4 (249.5–288.4)	362	16	156.0 (140.4–173.0)	**0.58 (0.51–0.66)**	**<0.0001**
	None	841	30	302.6 (282.3–323.8)	602	26	259.5 (239.2–281.1)	0.86 (0.77–0.95)	0.004
Tackler speed	Static	1264	45	454.8 (430.1–480.6)	1545	67	665.9 (633.2–700.0)	**1.46 (1.36–1.58)**	**<0.0001**
	In motion	1199	43	431.5 (407.4–456.6)	598	26	257.8 (237.5–279.3)	**0.60 (0.54–0.66)**	**<0.0001**
	High speed	192	7	69.1 (59.7–79.6)	144	6	62.0 (52.3–73.1)	0.90 (0.72–1.12)	0.33
	Unknown	124	4	44.6 (37.1–53.2)	33	1	14.2 (9.7–20.0)	**0.32 (0.21–0.47)**	**<0.0001**
Ball carrier speed	Static	227	8	81.7 (71.4–93.0)	304	12	131.0 (116.7–146.6)	**1.60 (1.34–1.91)**	**<0.0001**
	In motion	2051	74	738.0 (706.4–770.7)	1556	72	670.7 (637.8–704.9)	0.91 (0.85–0.97)	0.004
	High speed	377	14	135.7 (122.3–150.1)	427	12	184.1 (167.0–202.4)	**1.36 (1.18–1.56)**	**<0.0001**
	Unknown	124	4	44.6 (37.1–53.2)	33	4	14.2 (9.8–20.0)	**0.32 (0.21–0.47)**	**<0.0001**

Adjusted alpha: <0.002.

[a] FPOC: first point of contact.

Table 4
Interactions in tackle characteristics between ball carriers and tacklers.

Tackler	Ball carrier	U15			U18		
		Pre-law change	Post-law change	Rate ratio	Pre-law change	Post-law change	Rate ratio
		N: rate/1000 tackles (95 % CI)	N: rate/1000 tackles (95 % CI)		N: rate/1000 tackles (95 % CI)	N: rate/1000 tackles (95 % CI)	
Bent at waist	Bent at waist	N = 157: 247.6 (210.4–289.5)	N = 131: 169.0 (141.3–200.6)	0.68 (0.54–0.87): $p = 0.0012$	N = 332: 308.6 (276.2–343.6)	N = 260: 245.3 (216.4–277.0)	**0.79 (0.67–0.94): $p = 0.0055$**
	Upright	N = 476: 750.8 (684.8–821.4)	N = 640: 825.8 (763.1–892.3)	1.10 (0.98–1.24): $p = 0.1152$	N = 732: 680.3 (631.9–731.4)	N = 789: 744.3 (693.3–789.1)	1.10 (0.99–1.21): $p = 0.0796$
	Diving	N = 1: 1.6 (0.4–8.8)	N = 1: 1.3 (0.3–7.2)	0.82 (0.01–64.2): $p = 0.8999$	N = 12: 11.1 (5.8–19.5)	N = 11: 10.4 (5.2–18.6)	0.93 (0.37–2.30): $p = 0.8667$
Upright	Bent at waist	N = 78: 88.4 (69.9–110.4)	N = 52: 70.3 (52.5–92.2)	0.79 (0.55–1.14): $p = 0.1990$	N = 120: 130.7 (108.4–156.3)	N = 49: 65.4 (48.4–86.5)	**0.50 (0.35–0.70): $p < 0.0000$**
	Upright	N = 801: 908.2 (846.4–973.3)	N = 687: 928.4 (860.2–1000.0)	1.02 (0.92–1.12): $p = 0.6717$	N = 787: 857.3 (798.4–919.3)	N = 698: 932.9 (864.0–1000.0)	1.09 (0.98–1.21): $p = 0.1088$
	Diving	N = 3: 3.4 (0.7–9.9)	N = 1: 1.4 (0.3–7.5)	0.40 (0.04–3.82): $p = 0.4241$	N = 11: 11.9 (6.0–21.4)	N = 2: 2.7 (0.3–9.6)	0.22 (0.05–1.01): $p = 0.0508$
Diving	Bent at waist	N = 21: 54.4 (33.7–83.2)	N = 2: 6.2 (0.7–22.2)	**0.11 (0.1–0.46): $p = 0.0002$**	N = 55: 89.6 (67.5–116.6)	N = 8: 17.9 (7.7–35.3)	**0.20 (0.08–0.42): $p < 0.0000$**
	Upright	N = 345: 893.7 (801.9–993.3)	N = 294: 907.4 (806.6–1000.0)	1.01 (0.87–1.19): $p = 0.8481$	N = 526: 856.7 (785.0–933.1)	N = 416: 932.7 (845.2–1000.0)	1.09 (0.96–1.24) $p = 0.1953$
	Diving	N = 20: 51.8 (31.6–80.0)	N = 28: 86.4 (57.4–124.9)	1.67 (0.91–3.12): $p = 0.0808$	N = 33: 53.7 (37.0–75.5)	N = 22: 49.3 (30.9–74.7)	0.92 (0.51–1.62) $p = 0.7626$
Static	Static	N = 109: 107.5 (88.3–129.7)	N = 89: 73.4 (59.0–90.4)	0.68 (0.51–0.91): $p = 0.0077$	N = 102: 80.7 (66.0–98.0)	N = 138: 89.3 (75.0–105.5)	1.11 (0.85–1.44): $p = 0.4381$
	In motion	N = 832: 820.5 (765.7–878.2)	N = 934: 771.3 (722.6–822.4)	0.94 (−0.86–1.03): $p = 0.1943$	N = 1042: 824.4 (775.1–876.0)	N = 1174: 760.0 (71.7–80.5)	0.92 (0.85–1.00): $p = 0.0558$
	High speed	N = 73: 71.9 (56.4–90.5)	N = 188: 155.2 (133.8–179.1)	**2.15 (1.64–2.87): $p < 0.0000$**	N = 120: 94.9 (78.7–113.5)	N = 233: 150.9 (132.1–171.5)	**1.59 (1.27–2.00): $p = < 0.0000$**
In motion	Static	N = 122: 153.8 (127.8–183.7)	N = 142: 241.5 (203.4–284.6)	**1.56 (1.22–2.02): $p = 0.0003$**	N = 119: 99.2 (82.2–118.8)	N = 161: 269.2 (229.2–314.2)	**2.71 (2.13–3.47): $p < 0.0000$**
	In motion	N = 611: 770.5 (710.6–834.1)	N = 379: 444.6 (581.3–712.8)	0.84 (0.73–0.95): $p = 0.0061$	N = 975: 813.2 (762.9–865.9)	N = 369: 617.1 (555.7–683.3)	**0.76 (0.67–0.86): $p < 0.0000$**
	High speed	N = 60: 75.7 (57.7–97.4)	N = 67: 113.9 (88.3–144.7)	1.51 (1.05–2.17): $p = 0.0216$	N = 105: 87.6 (71.6–106.0)	N = 68: 113.7 (88.3–144.2)	1.30 (0.94–1.78): $p = 0.963$
High speed	Static	N = 2: 16.5 (2.0–59.7)	N = 2: 18.5 (2.2–66.9)	1.12 (0.08–15.5) $p = 0.9149$	N = 6: 31.3 (11.5–68.0)	N = 5: 34.7 (11.3–81.0)	1.11 (0.27–4.37): $p = 0.8587$
	In motion	N = 6: 49.5 (18.2–107.9)	N = 16: 148.1 (84.7–240.6)	2.98 (1.11–9.32) $p = 0.0177$	N = 34: 177.0 (122.6–247.5)	N = 13: 90.3 (48.1–154.4)	0.51 (0.25–0.99): $p = 0.0340$
	High speed	N = 113: 993.9 (769.7–1000.0)	N = 90: 833.3 (670.1–1000.0)	0.89 (0.67–1.19) $p = 0.4213$	N = 152: 791.7 (670.8–928.0)	N = 126: 875.0 (728.9–1000.0)	1.11 (0.87–1.41): $p = 0.4063$
High on ball carrier	High on tackler	N = 82: 611.9 (486.7–759.6)	N = 113: 672.6 (554.3–808.7)	1.10 (0.82–1.48): $p = 0.5166$	N = 119: 629.6 (51.6–753.4)	N = 154: 754.9 (640.4–884.0)	1.20 (0.94–1.54): $p = 0.1369$
	Medium on tackler	N = 0:	N = 1: 6.0 (1.5–33.2)	NA	N = 2: 10.6 (1.3–38.2)	N = 1: 4.9 (0.1–27.3)	0.46 (0.08–8.90): $p = 0.5826$
	Low on tackler	N = 0:	N = 0:	NA	N = 0:	N = 0:	NA
	Ground	N = 4: 29.9 (8.1–76.4)	N = 5: 29.8 (9.7–69.5)	1.0 (0.21–5.02):	N = 7: 37.0 (14.9–76.3)	N = 2: 9.8 (11.9–35.4)	0.26 (0.03–1.39): $p = 0.0872$
	Equipment	N = 0:	N = 0:	NA	N = 0:	N = 0:	NA
	None	N = 48: 358.2 (264.1–474.9)	N = 49: 291.7 (215.8–385.6)	0.81 (0.54–1.24): $p = 0.3132$	N = 61: 322.8 (246.9–414.6)	N = 47: 230.4 (169.3–306.4)	0.71 (0.48–1.06): $p = 0.0823$
Medium on ball carrier	High on tackler	N = 11: 27.8 (13.9–49,7)	N = 4: 6.0 (1.6–15.3)	0.21 (0.05–0.73): $p = 0.0058$	N = 9: 18.5 (8.5–35.1)	N = 9: 11.5 (5.2–21.7)	0.62 (0.22–1.76): $p = 0.3189$
	Medium on tackler	N = 4: 10.1 (2.8–25.9)	N = 5: 7.5 (2.4–17.4)	0.74 (0.16–3.72): $p = 0.6553$	N = 14: 28.7 (15.7–48.2)	N = 14: 17.8 (9.7–28.9)	0.62 (0.27–1.40): $p = 0.2115$
	Low on tackler	N = 0:	N = 0:	NA	N = 0:	N = 1: 1.3 (0.3–7.1)	NA
	Ground	N = 37: 93.4 (65.8–128.8)	N = 32: 47.8 (32.7–67.4)	0.51 (0.31–0.84): $p = 0.0057$	N = 52: 106.8 (79.7–140.0)	N = 49: 62.3 (46.1–82.4)	0.58 (0.39–0.88): $p = 0.0072$
	Equipment	N = 0:	N = 0:	NA	N = 0:	N = 0:	NA
	None	N = 344: 868.7 (779.3–965.5)	N = 629: 938.8 (866.9–1000.0)	1.08 (0.95–1.24): $p = 0.2468$	N = 412: 846.0 (766.3–931.8)	N = 713: 907.1 (841.8–976.2)	1.07 (0.95–1.21): $p = 0.2594$
Low on ball carrier	High on tackler	N = 1: 6.3 (1.6–35.0)	N = 0:	NA	N = 0:	N = 0:	NA
	Medium on tackler	N = 1: 6.3 (1.6–35.0)	N = 0:	NA	N = 3: 18.1 (3.7–52.8)	N = 1: 7.1 (0.2–39.8)	0.40 (0.08–4.92): $p = 0.4654$
	Low on tackler	N = 0:	N = 0:	NA	N = 0:	N = 0:	NA
	Ground	N = 9: 56.6 (25.9–107.5)	N = 1: 10.4 (0.3–58.0)	0.1.33: $p = 0.0714$	N = 16: 96.4 (55.1–156.5)	N = 7: 50.0 (20.1–103.0)	0.52 (0.18–1.33): $p = 0.1457$
	Equipment	N = 0:	N = 0:	NA	N = 0:	N = 0:	NA
	None	N = 148: 930.8 (786.9–1000.0)	N = 95: 989.6 (800.6–1000.0)	1.06 (0.81–1.38): $p = 0.6392$	N = 147: 885.5 (748.2–1000.0)	N = 132: 942.9 (788.9–1000.0)	1.06 (0.84–1.36): $p = 0.6008$

High: head/neck/shoulder; medium: hip/torso/arm; low: upper leg, knee, lower leg; other: equipment/other player; **adjusted alpha: <0.006**.

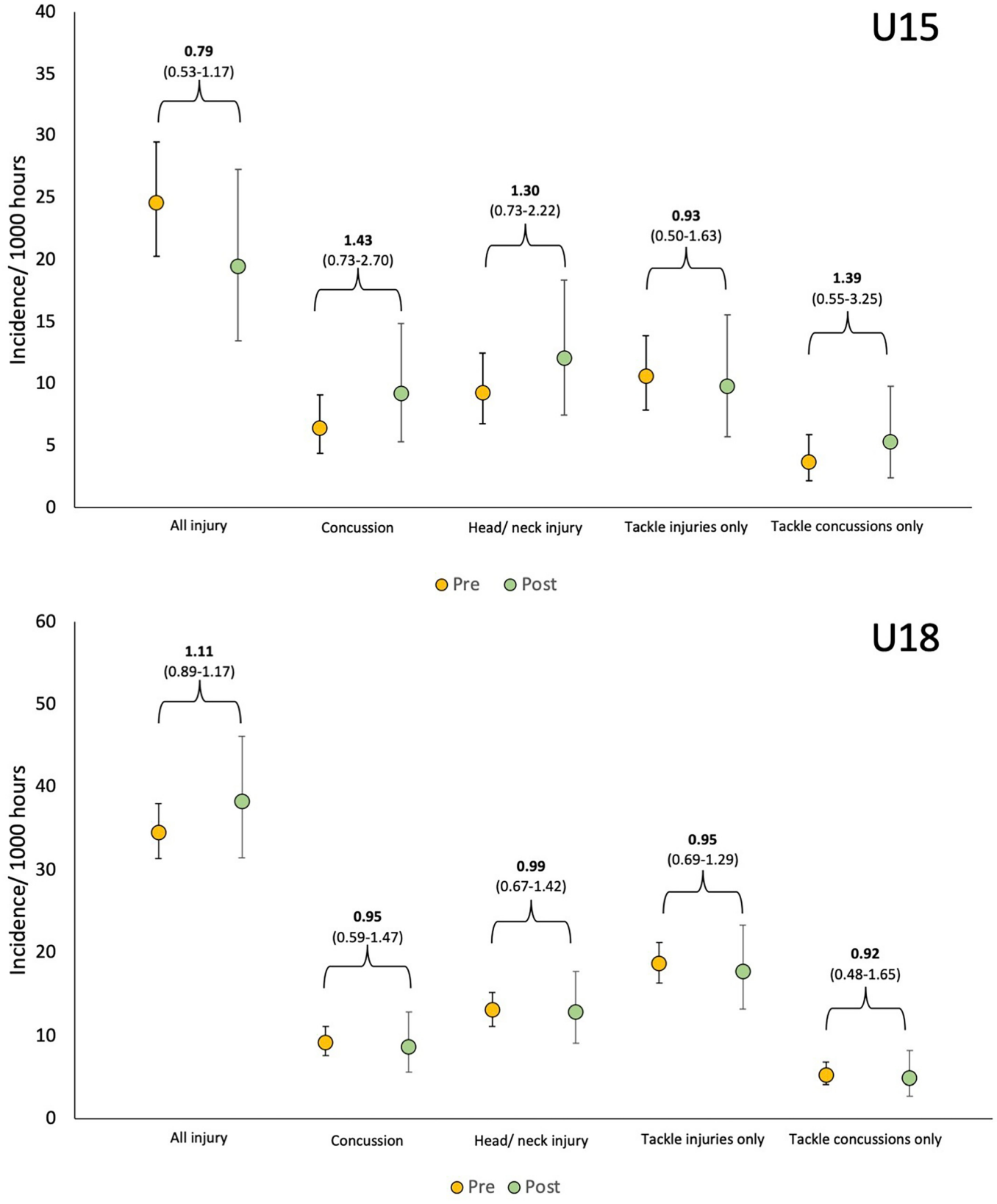

Fig. 1. Rate ratios (95 % CIs) in U15 and U18 rugby players pre and post law change for all injury, concussion, head/neck injury, tackle-related injury, and tackle related concussion.

groups. However, this did not translate to injury outcomes with no significant differences in the incidence or severity for any injury outcome following the lowered tackle height law for either the U15 or U18 age group. The injury incidence was higher for U18 match play compared with U15 both pre-law change and post-law change.

4.1. Player technique in the tackle

After the law change, there was evidence of a change in player tackle technique, with reductions in shoulder and armpit height tackles of 38 % at U15 and 23 % at U18. This was supported by the finding that tacklers

were significantly more often bent at the waist at both U15 (34 % increase) and U18 (18 % increase). Taken together, the changes in observed player tackle technique were commensurate with the law makers' intention to reduce the tackler's height of contact on the ball carrier. Within the law change, there was no requirement for the ball carrier to change their technique when entering the tackle and the current analyses showed that there was even an increase in the point estimate for upright ball carries for U18 and reductions in bent at the waist ball carries post-law change for U15. This was reflected in tackles when the tackler was bent at the waist, with associated post-law change reductions in the ball carrier also bent at the waist in both age groups. Post-law change, both U15 and U18 tacklers were in a static position immediately pre-contact in 23 % and 46 % more tackles, respectively, suggesting that they may have taken time to set their position and adopt the bent position. Given that changes in tackle laws are relatively rare, there are few studies with which to compare the current findings. One study in men's elite level English rugby union introduced the same change in tackle height as the current study and demonstrated tacklers adopting a bent body position more often and making initial contact with the head/neck and shoulder and armpit less often.[7] In the current study, there was no post-law change difference in the proportion of tackles made at head/neck height in either age group, but it should be noted that the proportion of these tackles was relatively low with less than 3 % and 4 % at U15 and U18, respectively. Based on an estimate of 170 to 200 tackles per game at these levels,[13] this equates to approximately five to eight head/neck high tackles per game.

4.2. Injury outcomes

Post-law change, there was no change in incidence for the U15 or U18 age groups for all injuries combined, concussions, head/neck injuries, all tackle injuries or concussions occurring in the tackle. The only other two studies which assessed law changes in rugby union tackle height (shoulder to armpit level) in English men's elite level rugby[7] and South African men's university level[8] also showed no reductions in injury incidence, thus demonstrating the challenge in reducing injuries despite favourable changes in player tackle technique. There are some possible explanations for the current findings. It should be considered that in the current study, there was only a small change in the legal height of the tackle (from the line of the shoulder to line of the armpit) resulting in the percentage of tackles above the armpit pre- to post-tackle height change reducing from 17 % to 12 % of all tackles at U15 and 12 % to 10 % at U18. These were possibly not large enough changes to reduce the incidence of injury, particularly given the relatively small proportion of all tackles both pre- and post-tackle height change which were made at the height of the ball carrier's head/neck and shoulder and armpit. As such, additional modifications to the tackle could be considered to further reduce head to upper body proximity contacts/collisions, thus potentially reducing head injuries. Indeed, as of July 2023, the legal maximum height of the tackle in English community rugby union was lowered to the base of the sternum and World Rugby has also recommended that rugby governing bodies worldwide adopt this tackle height. In changing some of the players' tackling techniques, it is possible that the mechanism of injury may have changed; for example, both U15s and U18s demonstrated a higher propensity of initial head contacts of the tackler to the hip and torso of the ball carrier. There is also the possibility that the benefits of tackling at a lower body height may have been offset by impaired tackle technique, given that players had not played rugby for approximately sixteen months prior to the start of the 2021/22 season because the 2020/21 season was cancelled due to Covid-19. However, the extent to which this lay-off may have adversely affected the players' tackle technique is difficult to speculate on, given that teams would have received varying amounts of training prior to the season starting. The tackle coding analysis in the current study did not identify injurious tackles on match footage and therefore we could not determine the characteristics of tackles which caused injuries, but this is an avenue for future research.

It is noteworthy that armpit-height tackles were previously the law at all age groups up to U14 in England, and therefore in the current study, the U15 players in the post-law period will have only ever tackled at the armpit height. The post-law change U15s were therefore not learning a new technique, whilst the U18 players would have previously tackled up to the shoulder level and may have had to adapt their technique following the law change. In this scenario, it may be expected that the U15 players would demonstrate a lower tackle technique than U18 players, given that they are more used to tackling below the armpit. This supposition was borne out in the post-law change data where the proportion of tackles above the armpit (head/neck and shoulder and armpit) was higher in the U18s than the U15s (Tables 1 and 2).

The significantly lower penalisation rate at U18 post-law change was unexpected and difficult to explain. However, in two of the pre-law change games, there were two games in which 20 penalties were awarded, thus accounting for the majority of the 68 total penalties across all sixteen games. Indeed, irrespective of which tackle height was in law in the current study, there was a particularly low penalisation (combined free kick or penalties) rate in both age groups relative to the proportions of tackles to the head/neck pre-law change and above the armpit line post-law change. Player behaviour change is shaped by laws but is also influenced by referee enforcement, and the low sanctioning rate may have not offered the appropriate deterrent to players performing head/neck height tackles, possibly explaining why there was not a greater reduction in tackles above the line of the armpit post-law change.[14] These sanctioning rates may have been due to the games within this study being officiated by referees with varying levels of experience. Whilst they would have received communication about the law change from the schools' rugby national organising body, it is not clear what their knowledge and attitudes were to officiating this law change. It should also be acknowledged that the on-field referee has one opportunity during a live game to assess the legality of each tackle whereas the match coder is able to watch a tackle on multiple occasions and at slower speeds, possibly leading to some differences in interpretation of tackle height and legality.[14]

A further point for consideration is that a previous study showed that over three phases of a rugby season with a lower tackle height, a positive change in tackle technique was only demonstrated in the final season phase, possibly due to stricter sanctioning in the second phase of the season.[14] Most of the matches in the current study were played over a twelve-week period and therefore this may not have provided sufficient opportunity for players to change their tackle technique and for referees to adjust their sanctioning.

4.3. Limitations

The current study did have some limitations which should be acknowledged. The match footage was derived from a single camera, allowing only one angle, which made some tackles difficult to code through being obscured, resulting in some outcomes having to be coded as unknown. There was a longer period of injury data collection and tackle analysis pre-law change compared with post, which limited a longer-term assessment of these tackle and injury trends; it has been found previously that there may be a time lag before positive player tackle technique changes are observed following a tackle height law change.[15] The current study did not include any contextual information relating to coach, player and referee knowledge and attitudes regarding this law change. Given that there were not any formal governing body coaching courses related to the tackle height change, it is possible that there may have been some variation between teams in the amount of tackle training preparation prior to the post-law change which may have affected player tackle technique between different teams. Moreover, there was no rugby played due to Covid-19 in

the 2020/21 season and this may have influenced player skills and conditioning, particularly at the start of the post-law change (2021/22) season. It should be acknowledged that despite invitations to take part in the current study being sent to schools playing at a range of playing levels, the participating schools were largely private (fee paying) and high performing publicly funded schools playing a high standard of rugby. As such, the population may not be representative of all U15 and U18 rugby being played across England.

5. Conclusion

This study demonstrated that a law change to lower the tackle height in the youth game was successful in changing tackle techniques behaviours as intended; however, there were no associated reductions in injury outcomes after one season of the lowered tackle height. Further lowering of the tackle height in the youth game may provide more opportunity for coaches, players and referees to adjust tackle technique further and potentially reduce injury rates.

Confirmation of ethical compliance

Ethical approval was obtained from the Research Ethics Approval Committee for Health (REACH) at the University of Bath (EP-17/18-167).

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CRediT authorship contribution statement

Simon P. Roberts: Conceptualization, Methodology, Investigation, Formal analysis, Supervision, Writing – original draft. **Stephen W. West:** Formal analysis, Writing – original draft. **Matthew V. Hancock:** Validation, Investigation, Data curation, Writing – review & editing. **Craig Barden:** Investigation, Data curation, Writing – review & editing. **Jac Powell:** Validation, Investigation, Data curation. **James C. Brown:** Methodology, Writing – review & editing. **Vanda White:** Methodology, Writing – review & editing. **Isla J. Shill:** Methodology, Writing – review & editing. **Carly D. McKay:** Methodology, Writing – review & editing. **Simon Kemp:** Conceptualization, Methodology, Supervision. **Rachel Faull-Brown:** Conceptualization, Resources. **Keith A. Stokes:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of interest statement

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2025.09.008.

References

1. Rugby, W. Global rugby participation increasing ahead of Rugby World Cup 2023. Retrieved 20/03/2024 from: https://www.rugbyworldcup.com/2023/news/836825/global-rugby-participation-increasing-ahead-of-rugby-world-cup-2023 2023.
2. West SW, Shill IJ, Bailey S et al. Injury rates, mechanisms, risk factors and prevention strategies in youth rugby union: what's all the ruck-us about? A systematic review and meta-analysis. *Sports Med* 2023;53(7):1375-1393. doi:10.1007/s40279-023-01826-z.
3. Hancock MV, Barden C, Roberts SP et al. Match injuries in English schoolboy rugby union. *BMJ Open Sport Exerc Med* 2024;10(1):e001740. doi:10.1136/bmjsem-2023-001740.
4. West SW, Starling L, Kemp S et al. Trends in match injury risk in professional male rugby union: a 16-season review of 10 851 match injuries in the English Premiership (2002–2019): the Professional Rugby Injury Surveillance Project. *Br J Sports Med* 2021;55(12):676-682. doi:10.1136/bjsports-2020-102529.
5. Cross MJ, Tucker R, Raftery M et al. Tackling concussion in professional rugby union: a case-control study of tackle-based risk factors and recommendations for primary prevention. *Br J Sports Med* 2019;53(16):1021-1025. doi:10.1136/bjsports-2017-097912.
6. Tucker R, Raftery M, Kemp S et al. Risk factors for head injury events in professional rugby union: a video analysis of 464 head injury events to inform proposed injury prevention strategies. *Br J Sports Med* 2017;51(15):1152-1157. doi:10.1136/bjsports-2017-097895.
7. Stokes KA, Locke D, Roberts S et al. Does reducing the height of the tackle through law change in elite men's rugby union (The Championship, England) reduce the incidence of concussion? A controlled study in 126 games. *Br J Sports Med* 2021;55(4):220-225. doi:10.1136/bjsports-2019-101557.
8. van Tonder R, Starling L, Surmon S et al. Tackling sport-related concussion: effectiveness of lowering the maximum legal height of the tackle in amateur male rugby — a cross-sectional analytical study. *Inj Prev* 2023;29(1):56-61. doi:10.1136/ip-2022-044714.
9. Fuller CW, Molloy MG, Bagate C et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Clin J Sport Med* 2007;17(3):177-181. doi:10.1097/JSM.0b013e31803220b3.
10. Bahr R, Clarsen B, Derman W et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). *Br J Sports Med* 2020;54(7):372-389. doi:10.1136/bjsports-2019-101969.
11. Hendricks S, Till K, den Hollander S et al. Consensus on a video analysis framework of descriptors and definitions by the Rugby Union Video Analysis Consensus group. *Br J Sports Med* 2020;54(10):566-572. doi:10.1136/bjsports-2019-101293.
12. Holm S. A simple sequentially rejective multiple test procedure. *Scand J Stat* 1979;6(2):65-70.
13. Till K, Hendricks S, Scantlebury S et al. A global perspective on collision and non-collision match characteristics in male rugby union: comparisons by age and playing standard. *Eur J Sport Sci* 2023;23(7):1131-1145. doi:10.1080/17461391.2022.2160938.
14. van Tonder R, Hendricks S, Starling L et al. Tackling the tackle 2: evaluation of referee and player behavioural change as measures of implementation of a law variation in community-level male amateur rugby union. *J Sci Med Sport* 2024;27(1):63-70. doi:10.1016/j.jsams.2023.11.004.
15. Wright SP. Adjusted p-values for simultaneous inference. *Biometrics* 1992;48(4):1005-1013.