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

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Accepted 19 November 2019
Published Online First 19 December 2019

ABSTRACT

Objectives Most concussions in rugby union occur during tackles. We investigated whether legislation to lower maximum tackle height would change tackle behaviour, and reduce concussion incidence rate.

Methods In an observational evaluation using a prospective cohort design, 12 elite men's teams played in two competitions during the 2018/2019 season. The Championship (90 games) retained standard Laws of Rugby for the tackle; the Championship Cup (36 games) used revised laws—the maximum tackle height was lowered from the line of the shoulders on the ball carrier to the line of the armpits. Videos of tackles were analysed for ball carrier and tackler behaviour. Injury data were collected using standardised methods.

Results In the lowered tackle height setting, there was a significantly lower proportion of tackles; (1) in which ball carriers (rate ratio (RR) 0.83, 95% CI 0.79 to 0.86) and tacklers (RR 0.80, 95% CI 0.76 to 0.84) were upright, (2) in which the tackler's initial contact was to the ball carrier's head or neck (RR 0.70, 95% CI 0.58 to 0.84) and (3) in which initial contact was above the line of the ball carrier's armpit (RR 0.84, 95% CI 0.80 to 0.88). Concussion incidence rate did not differ between conditions (RR 1.31, 95% CI 0.85 to 2.01). Unexpectedly, compared with the standard tackle height setting, tacklers in the lowered tackle height setting were themselves concussed at a higher rate as measured by; (1) incidence (RR 1.90, 95% CI 1.05 to 3.45) and (2) concussions per 1000 tackles (2.09, 95% CI 1.15 to 3.80).

Conclusions Legislating to lower the height of the tackle meant that tacklers made contact with the ball carrier's head and neck 30% less often. This did not influence concussion incidence rates. Tacklers in the lowered tackle height setting suffered more concussions than did tacklers in the standard tackle height setting.

Linked

► http://dx.doi.org/10.1136/bjsports-2020-101983

Check for updates

To cite: Stokes KA, Locke D, Roberts S, *et al*. *Br J Sports Med* 2021;**55**:220–225.

INTRODUCTION

Concussion has a match incidence rate of 17.9 per 1000 hours in elite men's rugby union, representing 20% of all match injuries.[1] Over 50% of concussions occur in the tackle,[2] partly because it is a dynamic and physical event, and partly because tackles are frequent game events. Observational studies examining head injury risk in the tackle show increased risk from active shoulder tackles, front-on tackles, high-speed tackles, higher height contacts on the ball carrier by the tackler, players accelerating into tackles and head-to-head contact.[3–5] Illegal tackles (high tackles, use of the elbow, tip tackles and tackles in the air) carry a significantly greater risk of concussion than other tackle types but occur relatively rarely.[3–5] However, while both ball carriers and tacklers are at risk, illegal tackles tend to injure the ball carrier more often than the tackler, whereas all legal tackle types tend to injure the tackler more often than the ball carrier.[4]

Law changes have great potential as injury reduction measures.[6 7] However, considering the types of tackles that have a high concussion risk, it is challenging to directly reduce player speed or acceleration, or to require players to make more passive/non-dominant tackles. In contrast, focusing on lowering tackle height, with a particular emphasis on reducing head-to-head contacts in front-on tackles when both players are upright, has the potential to reduce concussion. Based on observational evidence,[4 5] an expert multidisciplinary World Rugby working group[8] comprising coaches, players and match officials recommended encouraging tacklers to perform more mid-height tackles (ie, contact with the ball carrier's torso) than higher tackles (ie, contact above the line of the armpit on the ball carrier) to reduce concussion risk for both ball carriers and tacklers.

We aimed to determine whether varying the laws of the game to reduce the maximum height of the legal tackle from the line of the shoulders of the ball carrier to the line of the armpit in elite men's rugby union: (1) changes tackle behaviour and (2) reduces the incidence rate of concussion and other injuries.

METHODS

Study design and participants

We employed an observational evaluation, using a prospective cohort design, of a policy-led law variation in which nine rounds of matches were played under standard laws (n=54 matches), six rounds of matches were played with law variation (n=36 matches) and finally six rounds of matches were played when reverting to standard laws (n=36 matches). Participants were players in first-team matches in the second tier of elite men's rugby in England during the 2018/2019 season. Data was collected during rounds 1–9 (pre-law variation) and 10–15 (post-law variation) of the Championship (a league involving 12 teams), and during rounds 1–6

Table 1 Tackle characteristics analysed

Tackles	
Tackle events	Counted as a single tackle regardless of the no of players involved.
Tackle actions	Counted as the total no of tackles made (eg, a tackle event involving two tacklers would be coded as two tackle actions).
Players in tackle	
1 player tackle	Only 1 defender/tackler is involved at any point in the tackle up to when it is completed.
2 player tackle	2 defenders/tacklers are involved at any point in the tackle up to when it is completed.
3 player tackle	3 defenders/tacklers are involved at any point in the tackle up to when it is completed.
Tackle type	
Active shoulder	First contact is with the tackler's shoulder, and the tackler drives or attempts to drive the ball carrier backwards.
Passive shoulder	First contact is with the tackler's shoulder and the tackler does not drive or attempt to drive the ball carrier back.
Tap tackle	Tackler trips the ball carrier with a hand on the lower limb below the knee.
Smother tackle	Tackler uses the chest and attempts to wrap both arms around the ball carrier.
Lift (illegal)	Tackler lifts the ball carrier's hips above the BC head.
No arms (illegal)	Tackler impedes the ball carrier without use of their arms.
High tackle (illegal)	Penalised by the referee for contact being high.
Tackle in the air (illegal)	Penalised by the referee for defender making contact with carrier in the air.
Point of contact	
Head and neck	Initial contact on head or neck of ball carrier.
Shoulder and armpit	Initial contact above the line of the armpit and below top of shoulders or ball carrier.
Torso	Initial contact above midpoint of hips and below the line of the armpit of ball carrier.
Upper leg	Initial contact above midpoint of knee and below midpoint of hips of ball carrier.
Lower leg	Initial contact from foot to midpoint of knee of ball carrier.
Tackle direction	
Front-on	Tackler makes contact on the front of the BC.
On angle	Tackler makes contact with the BC on an angle.
Side on	Tackler makes contact with the side of the BC.
From back	Tackler makes contact with the BC from behind.
Body position	
Tackler/carrier upright	No bend at the waist/hips at the point of contact.
Tackler/carrier partially bent	Approximately 30°–60° bend at waist at the point of contact.
Tackler/carrier fully bent	Greater than approximately 60° bend at waist at the point of contact.
Tackler/carrier diving	Diving at the point of contact.
Tackler and carrier speed	
Static	Player has feet planted in the final moments before contact.
In motion	Player is in motion (walking/jogging) but not at 'high speed'.
High speed	Player is at fast pace or sprinting.

(law variation) of the Championship Cup (the same 12 teams in three groups of four teams). We did not directly include patient and public involvement, but the steering group included key stakeholders (ie, coaches, referees and policy-makers).

The law variation being evaluated

The Championship was played under standard Laws of the Game relating to the tackle (Law 9.13).[9] The Championship Cup was played under revised Laws regarding the tackle; specifically, the height of the legal tackle was reduced from the line of the shoulders on the ball carrier to the line of the armpits.

Outcome measures

Following checks for interanalyst agreement, 10 experienced game analysts coded 52 variables to describe game characteristics (Sportscode V.11). The tackle was defined as 'any event where one or more tacklers attempted to stop or impede the ball carrier whether or not the ball carrier was brought to ground'.[10] Tackle events were coded as the number of tackles regardless of the number of players involved. Tackle actions were coded as the total number of tackles made (eg, a tackle event involving two tacklers would be coded as two tackle actions). Tackle coding was developed from previous studies[4 5 10] (table 1). During piloting, the reliability of identifying 'accelerating players[5]' was poor; therefore, this variable was not coded. Penalties and yellow and red cards were captured from game analysis.

In both competitions, the standardised head injury assessment (HIA)[11] protocol was used to assist team doctors' clinical diagnosis of concussion. The HIA protocol reduces the proportion of players that continue playing after suffering a concussion.[12] Club medical personnel recorded concussions (CSx, Auckland, New Zealand) and 24 hours time-loss injuries (Rugby Squad, The Sports Office UK), along with the game event at the time of injury. Total exposure was calculated as 30 players multiplied by 80 min multiplied by the number of matches played.

Data analysis

Game events are reported as average number of events per match. Tackle characteristics are reported per 100 tackle actions. Match injury incidence rate and concussion incidence rate is reported per 1000 player hours. Propensity is reported as the number of injuries per 1000 tackle events for ball carriers and per 1000 tackle actions for tacklers. For incidence, propensity, and game events, rate ratios (RRs) were calculated between standard and

Table 2 Game events expressed per game

	Championship (standard tackle height)	Championship cup (lowered tackle height)	Rate ratio (95% CI)
Ball-in-play (min:sec)	38:08	35:51	0.94 (0.93 to 0.95)*
Ball out of play (min:sec)	51:27	51:30	1.00 (0.99 to 1.01)
Carries	202	187	0.93 (0.90 to 0.95)*
Tackle events†	199	183	0.92 (0.89 to 0.93)*
Total tackles‡	291	264	0.91 (0.89 to 0.93)*
Passes	241	221	0.92 (0.89 to 0.94)*
Offloads	15	15	1.00 (0.91 to 1.10)
Steal attempts	58	57	0.98 (0.93 to 1.03)
Rucks	171	155	0.91 (0.88 to 0.93)*
Line-outs	26	29	1.12 (1.04 to 1.20)*
Scrums	13	14	1.08 (0.97 to 1.20)

*Significant difference (p<0.05)
†Number of tackles per game.
‡Total number of tacklers per game

lowered tackle height periods and were considered significant if the 95% CIs did not include 1.0 and p<0.05 based on a two-tailed Z test for the comparison of RRs.[13]

RESULTS

Participants

The standard tackle height period comprised 90 matches (3600 hours of exposure; pre-law variation, 54 matches, 2160 hours; post-law variation, 36 matches, 1440 hours). The reduced tackle-height period comprised 36 matches (1440 hours of exposure). Ninety-nine players played only in matches during the standard tackle height period, 62 players played only in matches during the lowered tackle height period and 405 players played in both. Four hundred and eighty eight players (86% of all players) gave consent for their injury data to be used in the analysis.

Game events

Ball-in-Play time was significantly lower in the lowered tackle height period, resulting in significantly fewer carries, tackle events, total tackles, passes and rucks per game (table 2). There were significantly more line-outs per game in the lowered tackle height period. Expressing game events per minute of Ball-in-Play, there were no differences between lowered tackle height and standard tackle height periods (data not shown).

Tackle behaviour

During the standard tackle height period, 36% of 26 095 total tackle actions were one-player tackles, compared with 38% of 9515 total tackle actions during the lowered tackle height period (RR 1.05, 95% CI 1.01 to 1.09, z=2.620, p=0.01). There were no differences in two-player (standard tackle height, 59% vs lowered tackle height, 57%; RR 0.98, 95% CI 0.95 to 1.01, z=1.549, p=0.12) or three-player tackle actions (standard tackle height, 5% vs lowered tackle height, 5%; RR 0.90, 95% CI 0.81 to 1.01, z=1.834, p=0.07). During the lowered tackle height period, there was a significantly lower rate of active shoulder tackles and smother tackles, with a significantly greater rate of passive shoulder and arm tackles (table 3).

During the lowered tackle height period, ball carriers entered the tackle in an upright or a fully bent position less often, and partially bent more often. Tacklers entered the tackle upright less often, and fully bent more often. The proportion of tackles

Table 3 Tackle characteristics (type, body position, initial point of contact on ball carrier) expressed per 100 tackle actions

	Championship (standard tackle height)	Championship cup (lowered tackle height)	Rate ratio (95% CI)
Tackle type			
Active shoulder	39.1	31.7	0.81 (0.78 to 0.84)*
Passive shoulder	34.2	40.9	1.19 (1.15 to 1.24)*
Arm	10.3	12.4	1.21 (1.13 to 1.30)*
Smother	15.7	14.2	0.90 (0.85 to 0.96)*
Other†	0.7	0.8	1.23 (0.94 to 1.62)
Carrier body position			
Carrier upright	35.0	29.0	0.83 (0.79 to 0.86)*
Carrier partially bent	43.4	54.3	1.25 (1.21 to 1.29)*
Carrier fully bent	19.5	14.7	0.75 (0.71 to 0.80)*
Carrier diving	2.1	2.0	0.99 (0.84 to 1.16)
Tackler body position			
Tackler upright	25.0	20.0	0.80 (0.76 to 0.84)*
Tackler partially bent	37.8	38.5	1.02 (0.98 to 1.06)
Tackler fully bent	28.2	32.4	1.15 (1.10 to 1.20)*
Tackler diving	9.0	9.1	1.02 (0.94 to 1.10)
Initial point of contact on ball carrier			
Head and neck	2.2	1.5	0.70 (0.58 to 0.84)*
Shoulder and armpit	28.8	24.5	0.85 (0.81 to 0.89)*
Torso	49.8	50.7	1.02 (0.98 to 1.05)
Upper leg	16.7	20.7	1.24 (1.17 to 1.31)*
Lower leg	2.5	2.6	1.03 (0.89 to 1.19)

*Significant difference (p<0.05)
†Other tackle types are: tap, lift, no arms, tackled in air.

in which the initial point of contact was to the ball carrier's head or neck was significantly lower during the lowered tackle height period, and there was a significantly lower proportion of tackles with initial contact above the line of the armpit. There was also a significantly lower rate of tackles above the line of the armpit when the ball carrier was upright or partially bent (table 4).

Concussions

In most rounds of competition the number of concussions was within 1 SD of the mean for the study, apart from round eight of

Table 4 Initial point of contact (above or below line of the armpit) to the ball carrier for tackles by ball carrier body position expressed per 100 tackle events

	Championship (standard tackle height)	Championship cup (lowered tackle height)	Rate ratio (95% CI)
Carrier upright	n=9086	n=2734	
Above armpit line	26.3	23.2	0.88 (0.81 to 0.96)*
Below armpit line	73.7	76.8	1.04 (0.99 to 1.09)
Carrier partially bent	n=11 245	n=5124	
Above armpit line	30.2	23.8	0.79 (0.74 to 0.84)*
Below armpit line	69.8	76.2	1.09 (1.05 to 1.13)*
Carrier fully bent	n=5047	n=1382	
Above armpit line	41.2	40.2	0.97 (0.89 to 1.07)
Below armpit line	58.8	59.8	1.02 (0.94 to 1.10)
Carrier diving	n=537	n=193	
Above armpit line	30.7	20.7	0.67 (0.48 to 0.95)*
Below armpit line	69.3	79.3	1.14 (0.95 to 1.38)
All tackles	n=25 915	n=9433	
Above armpit line	31.0	26.0	0.84 (0.80 to 0.88)*
Below armpit line	69.0	74.0	1.07 (1.04 to 1.10)*

*Significant difference (p<0.05)

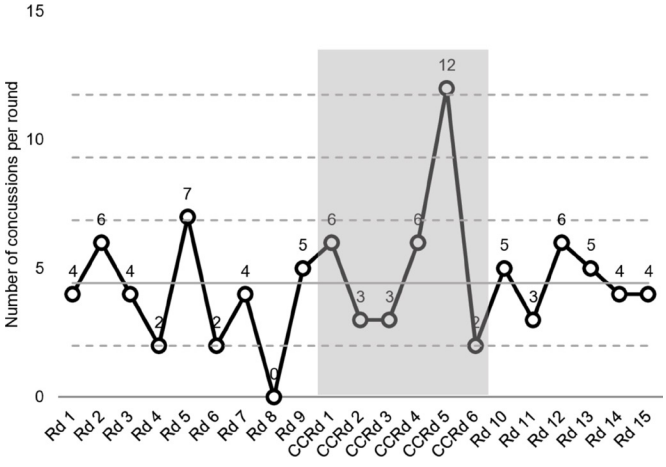

Figure 1 Number of concussions per round of competition. The shaded area is the lowered tackle height period. Solid grey line is mean for the whole period and dashed lines are 1, 2 and 3 SDs away from the mean. CCRd, Championship Cup Round; Rd, Championship Round.

the standard tackle height period (0 concussions) and round five of the lowered tackle height period (12 concussions; figure 1). In the standard tackle height period, incidence rate was 16.9 (95% CI 13.2 to 21.8) concussions per 1000 hours (61 concussions). Incidence rate in the pre control and post-law variation control periods was not significantly different (15.7, 95% CI 11.2 to 22.0, vs 18.8, 95% CI 12.9 to 27.3, concussions per 1000 hours, respectively; RR, 1.19, 95% CI 0.72 to 1.97, z=0.679, p=0.50). During the lowered tackle height period, incidence rate was 22.2 (95% CI 15.7 to 31.4) concussions per 1000 hours (32 concussions). Concussion incidence rate was not significantly different in the lowered tackle height and standard tackle height periods (RR 1.31, 95% CI 0.85 to 2.01, z=1.242, p=0.21; figure 2).

During the standard tackle height period, 45 out of 61 concussions (74%) occurred in tackles, of which tacklers sustained 56%. In the lowered tackle height period, 27 out of 32 concussions (84%) occurred in the tackle (67% to tacklers). Tackle concussion incidence rates for ball carriers were 5.6 per 1000 hours in the standard tackle height and 6.3 per 1000 hours in the lowered tackle height period (RR 1.13, 95% CI 0.51 to 2.47, z=0.293, p=0.77). Tackle concussion incidence rates for tacklers were 6.9 per 1000 hours in the standard tackle height and 13.2 per 1000 hours in the lowered tackle height period (RR 1.90, 95% CI 1.05 to 3.45, z=2.110, p=0.035). Propensity for concussion for ball carriers was not different in standard tackle height and lowered tackle height periods (1.1, 95% CI 0.7 to 1.7, vs 1.4, 95% CI 0.7 to 2.6, concussions per 1000 tackle events, respectively; RR 1.22, 95% CI 0.56 to 2.69, z=0.502, p=0.62). Propensity for concussion was lower in the standard tackle height than the lowered tackle height period for tacklers (1.0, 95% CI 0.6 to 1.4, vs 2.0, 95% CI 1.3 to 3.1, concussions per 1000 tackle actions, respectively; RR 2.09, 95% CI 1.15 to 3.80, z=2.429, p=0.02). Propensity for concussion when there was head contact during the tackle for ball carriers was not different in standard tackle height and lowered tackle height periods (4.6, 95% CI 3.0 to 7.2, vs 7.0, 95% CI 3.7 to 13.5, concussions per 1000 tackle events, respectively; RR 1.52, 95% CI 0.69 to 3.34, z=1.047, p=0.30), but it was lower in the standard tackle height than the lowered tackle height period for tacklers (3.7, 95% CI 2.5 to 5.5, vs 7.0, 95% CI 4.5 to 11.0, concussions per 1000 tackle actions, respectively; RR 1.90, 95% CI 1.05 to 3.46, z=2.114, p=0.03).

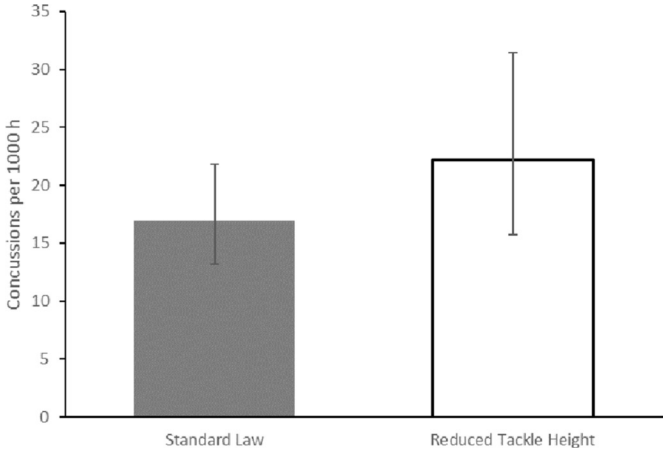

Figure 2 Mean (95% CIs) incidence rate of concussion in the standard tackle height and lowered tackle height periods.

All time-loss injuries

During the standard tackle height period, all time-loss injury incidence rate was 71.1 (95% CI 62.9 to 80.4) time-loss injuries per 1000 hours (256 injuries) compared with 70.8 (95% CI 58.3 to 86.0) time-loss injuries per 1000 hours (102 injuries) in the lowered tackle height period (RR 1.00, 95% CI 0.79 to 1.25, z=0.033, p=0.97). Time-loss injury incidence rate when tackling (standard tackle height, 14.4, 95% CI 11.0 to 19.0, time-loss injuries per 1000 hours vs lowered tackle height, 20.8, 95% CI 14.6 to 29.8, time loss injuries per 1000 hours; RR 1.44, 95% CI 0.92 to 2.26, z=1.597, p=0.11) or when being tackled (standard tackle height, 17.8, 95% CI 13.9 to 22.7, time-loss injuries per 1000 hours vs lowered tackle height, 23.6, 95% CI 16.9 to 33.0, time-loss injuries per 1000 hours; RR 1.33, 95% CI 0.88 to 2.01, z=1.337, p=0.18) were not different.

Sanctions for illegal play

During the standard tackle height period there were 19.4 (95% CI 18.5 to 20.3) penalties per match and 1.1 (95% CI 0.9 to 1.3) high tackle penalties per match, compared with 23.1 (95% CI 21.6 to 24.7) penalties per match (RR vs standard tackle height, 1.19, 95% CI 1.10 to 1.29, z=4.125, p<0.01) and 4.3 (95% CI 3.7 to 5.0) high tackle penalties per match during the lowered tackle height (RR vs standard tackle height, 3.99, 95% CI 3.10 to 5.15, z=10.698, p<0.01). There were 0.04 (95% CI 0.02 to 0.12) high tackle yellow cards per match in the standard tackle height period and 0.33 (95% CI 0.19 to 0.59) per match in the lowered tackle height period (RR, 7.50, 95% CI 2.42 to 23.25, z=3.490, p<0.01). There was one red card in each of the standard tackle height and lowered tackle height periods; both were for high tackles.

DISCUSSION

We explored how lowering the height of the legal tackle from the line of the shoulders on the ball carrier to the line of the armpit in elite men's rugby union changed player behaviour. During the lowered tackle height period, Ball-in-Play time was lower, reducing the number of game events (including tackles) but the overall pattern of the game was not altered. The characteristics of the tackle changed, with 15% fewer tackles above the line of the armpit, fewer head and neck contacts for ball carriers and more tackle events where tacklers were fully bent into contact. There was no change in concussion incidence, and the incidence

of all injuries did not change, but the incidence and propensity of concussions increased in tacklers.

Player behaviour

Ball-in-Play time was significantly lower in the lowered tackle height period, likely due to the time taken by the awarding of more penalties for high tackles and the resultant increase in line-outs following a kick for touch. Lower Ball-in-Play time resulted in fewer game events overall, but game events expressed per minute of Ball-in-Play time did not change, suggesting the overall shape of the game was retained. With lower Ball-in Play time in the lowered tackle height period, there were fewer tackle events per match. Tackler behaviour changed significantly in the lowered tackle height period, suggesting that tacklers targeted lower on ball carriers' bodies, in part by adopting a fully bent body position more often and being upright significantly less frequently. The number of tackles made above the line of the armpit of ball carriers and number of tackles in which there was initial contact with the head of ball carriers decreased. In this respect, lowering the tackle height was successful because tackler behaviour changed as intended. Part of the rationale for this study was that head injury risk is lower in tackles made below the line of the armpit with the tackler bent at the waist, since this reduces the risk of two players' heads clashing.[4 5] In addition, inertial head load, measured by the linear and angular acceleration of the tackler's head, is lower in tackles executed at the lower/midtrunk compared with the upper trunk.[14]

Concussions

Despite a desired change in tackler behaviour, concussion incidence rate did not decrease during the intervention; on the contrary there was a 30% increase in concussion incidence (non-significant). One week without any reported concussions in the standard tackle height period and 1 week with 12 reported concussions in the lowered tackle height period influenced these incidence comparisons (with these 2 weeks removed from the analysis the RR was 0.92, 95% CI 0.55 to 1.52). During the lowered tackle height period, a higher proportion of concussions occurred in the tackle. Furthermore, even though the number of head contacts to tacklers did not change, the propensity for concussion was greater for tacklers in all tackles and in tackles when head contact occurred. As a result, concussion incidence rate for tacklers during the lowered tackle height period was twice that in the standard tackle height period. The reasons for the greater propensity of concussion during the lowered tackle height period when head contact occurs is not immediately clear. The inciting event (ie, head contact) may have different risks depending on the nature of the tackle and therefore more detailed analysis is needed of how specific risk factors such as speed,[4 5] acceleration[4 5] and tackle technique[15] interact to influence overall risk. This study was not powered to answer these questions. Overall, lowering the tackle height was designed to reduce concussion in both tacklers and ball carriers, but this effect was not achieved, especially in tacklers.

Analysing video of tackle incidents showed that, during the lowered tackle height period, ball carriers entered the tackle upright less frequently and in a partially bent position more frequently (table 3). In this scenario, tacklers must fully bend at the waist to make a tackle below the line of the armpit. Therefore, lowering tackle height reduced the number of tackles that involved upright ball carriers and upright tacklers. We need to further develop existing research models of the tackle that typically involve a single tackler making a front on tackle.

Limitations

The observational design employed does not allow control over other elements that may change player behaviour over time, such as the weather and ground conditions, the time in the season, and the playing squads selected for matches. In particular, the relative importance placed on the two competitions in this study and, consequently, the playing squads selected, may have influenced the tackle skill of the players. In addition, concussion incidence rates were 20% higher in the post-law variation than the pre-law variation periods, despite the application of standard laws relating to tackle height in both periods. This might reflect a change in reporting due to greater focus on concussion because of the study. Two specific competition rounds in which lower than expected (in standard tackle height) and higher than expected (in lowered tackle height) number of concussions occurred (figure 1) also influenced the findings. Larger studies are required in cohorts with mature concussion reporting to overcome these issues.

Future studies should involve stakeholders (ie, players, coaches and referees) more closely and provide a longer preparatory period. Club coaches were involved in discussion regarding preparing players for the altered tackle height, but their feedback at the end of the study indicated mixed views as to whether reducing tackle height would reduce concussions; when asked at the end of the study, the majority of players felt that reducing tackle height would result in more, rather than less, concussions. Law changes have great potential in preventing injuries, but working with stakeholders on adoption and implementation might improve outcomes.

CONCLUSION

Reducing the maximum height of the legal tackle from the line of the shoulder to the line of the armpit in elite men's rugby resulted in desired changes in player behaviour. Ball carriers entered contact partially bent and tacklers entered contact fully bent at the waist more frequently. However, overall concussion incidence did not decrease and in tacklers both concussion incidence and propensity increased significantly. A better understanding of the interaction between ball carrier and tackler behaviour is needed to inform future trials of more context-specific and game-specific strategies to reduce concussion.

What are the findings?

- A specific law change influenced player behaviour in the dynamic game event of the rugby tackle.
- Legislating to lower the maximum height of the rugby tackle on the ball carrier reduced the number of tackles in which ball carriers and tacklers were upright, which was a primary target of the law variation.
- The law change was associated with a greater concussion incidence among tacklers.

How might it impact on clinical practice in the future?

- Law changes have the potential to change player behaviour, but they need to be tested in the competition setting.

Correction notice This article has been corrected since it published Online First. Various amendments have been made to the text throughout the article.

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Acknowledgements We would like to thank staff and players at all of the Championship Clubs (Bedford Blues, Cornish Pirates, Coventry Rugby, Doncaster

Knights, Ealing Trailfinders, Hartpury College, Jersey Reds, London Irish, London Scottish, Nottingham Rugby, Richmond, Yorkshire Carnegie) for their contribution to the study.

Contributors The study was designed by KAS, SK and DR. Data collection was carried out by KAS, SR, LH and DL. Data analysis was carried out by KAS, DL and RT. The first draft of the manuscript was prepared by KAS. All authors contributed to revisions of the manuscript and approved the submitted version.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests KAS, DL, LH and SK are employees of the Rugby Football Union, which is the governing body for Rugby Union in England. RT is employed by World Rugby, which is the governing body for the sport of Rugby Union and responsible for law changes in the sport.

Patient consent for publication Not required.

Ethics approval Ethics approval for collection of all injury data (REACH: EP 17/18 170) and specific concussion data (REACH: EP 16/17 286) was given by the University of Bath.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement No data are available.

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REFERENCES

1 Rugby Football Union. England professional rugby injury surveillance project 2017-18 season report 2019.
2 Cross M, Kemp S, Smith A, *et al*. Professional Rugby Union players have a 60% greater risk of time loss injury after concussion: a 2-season prospective study of clinical outcomes. *Br J Sports Med* 2016;50:926–31.
3 Tucker R, Raftery M, Fuller GW, *et al*. A video analysis of head injuries satisfying the criteria for a head injury assessment in professional rugby Union: a prospective cohort study. *Br J Sports Med* 2017;51:1147–51.
4 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;51:1152–7.
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;53:1021–5.
6 Beaudouin F, Aus der Fünten K, Tröß T, *et al*. Head injuries in professional male football (soccer) over 13 years: 29% lower incidence rates after a rule change (red card). *Br J Sports Med* 2019;53:948–52.
7 Emery C, Palacios-Derflingher L, Black AM, *et al*. Does disallowing body checking in non-elite 13- to 14-year-old ice hockey leagues reduce rates of injury and concussion? a cohort study in two Canadian provinces. *Br J Sports Med* 2019:bjsp orts-2019-101092.
8 World Rugby. New measures to limit contact with the head announced, 2016. Available: https://www.world.rugby/news/213339?lang=en [Accessed 17 Sep 2019].
9 World Rugby. Laws of the game, 2019. Available: https://laws.worldrugby.org/?law=showallbynumbers [Accessed 17 Sep 2019].
10 Fuller CW, Ashton T, Brooks JHM, *et al*. Injury risks associated with tackling in rugby Union. *Br J Sports Med* 2010;44:159–67.
11 World Rugby. HIA protocol. Available: https://playerwelfare.worldrugby.org/content/getfile.php?h=030cc0e5445023d2887628100863ace2&p=downloads/concussion/HIA_Protocol_Detailed_Description_Landscape_EN.pdf [Accessed 17 Sep 2019].
12 Fuller CW, Fuller GW, Kemp SPT, *et al*. Evaluation of World rugby's concussion management process: results from rugby world cup 2015. *Br J Sports Med* 2017;51:64–9.
13 Kirkwood BR, Sterne JAC. *Essential medical statistics*. 2nd edn. Wiley, 2003.
14 Tierney GJ, Richter C, Denvir K, *et al*. Could lowering the tackle height in rugby Union reduce ball carrier inertial head kinematics? *J Biomech* 2018;72:29–36.
15 Tierney GJ, Denvir K, Farrell G, *et al*. The effect of Tackler technique on head injury assessment risk in elite rugby Union. *Med Sci Sports Exerc* 2018;50:603–8.