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TITLE

The epidemiology of kicking injuries in professional Rugby Union: a 15-season prospective study

RUNNING TITLE

Kicking injury and match demands in Rugby

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ABSTRACT

PURPOSE

Whilst kicking in Rugby Union can be influential to match outcome, the epidemiology of kicking injuries remains unknown. This study therefore aimed to investigate the epidemiology of injuries attributed to kicking in professional rugby, including playing position-specific effects and differences in kicking volumes and kick types.

METHODS

Fifteen seasons of injury surveillance data and two seasons of match kicking characteristics from professional rugby players were analysed. Incidence, propensity and severity of kicking-related injuries were calculated together with the locations and types of these injuries. Position-related differences in match kicking types and volumes were also established.

RESULTS

Seventy-seven match and 55 training acute-onset kicking injuries were identified. The match-kicking injury incidence for backs was 1.4/1000 player-match-hours. Across all playing positions, the propensity for match kicking injury was 0.57 injuries/1000 kicks. Fly-halves sustained the greatest proportion of match kicking injuries (47%) and performed the greatest proportion of match kicks (46%); an *average* propensity for match kicking injury (0.58/1000 kicks). Scrum-halves executed 27% of match-related kicks but had a *very low* propensity for match kicking injury (0.17/1000 kicks). All other positional groups executed a small proportion of match-related kicks but a *high* propensity for match kicking injury. Ninety-two per cent of match kicking injuries occurred in the pelvis or lower limb, with the majority sustained by the kicking limb. 21% of all match kicking injuries were associated with the rectus femoris muscle.

CONCLUSION

Match-kicking profiles and kicking injuries sustained are position-dependent, which provides valuable insight for developing player-specific conditioning and rehabilitation protocols.

KEY WORDS

incidence, injury, injury surveillance, kick, propensity, rectus femoris, rugby

INTRODUCTION

Kicking has the ability to influence the outcome of professional Rugby Union (hereafter rugby) matches both directly by adding points via attempts at goal, and indirectly through manipulating territory which can lead to try-scoring opportunities[1,2] or relieve defensive pressure. While kicking is not the sole determinant of a team's success, more frequent kicking has been consistently associated with winning across a range of rugby competitions.[2–4] Team success is also known to be associated with player injury, as injuries within a squad affect player availability and hence final league and tournament position.[5,6] It is possible that injuries sustained by players who frequently kick may therefore play a role in limiting the effectiveness of their team. The epidemiology of injuries sustained in rugby activities has been extensively investigated,[7-19] and although kicking as a potential mechanism of injury has been reported in some studies,[15–18] it is frequently grouped alongside a combination of 'other' mechanisms. Given the importance of kicking for match outcome,[2–4] a more detailed consideration of the nature and causes of injuries sustained while kicking is clearly warranted. Whilst position-specific injury profiles have previously been considered,[10,20] these are likely to be affected by multiple position-specific events and the epidemiology of injury directly associated with kicking currently remains extremely limited.

Injury frequency is typically quantified through incidence (injuries per unit of time) or propensity (injuries per given number of events) calculations. Traditional methods of calculating match injury incidence include the total number of players on the pitch, and do not consider the number of players typically involved in a given match event. As backs perform considerably more kicks than forwards, and there are differences in the number of kicks completed by each member of the backs,[21] traditional calculations of incidence based on whole-team exposure may underestimate the true frequency of kicking-related injuries. Brown et al.[22] described the use of a modified incidence value based on players who were directly involved in a given injury event (e.g. only forwards or front row players were included in calculations of scrummaging injury incidence): therefore, including only backs in an incidence calculation of kicking-related injuries appears worthy of consideration. However, as kicking is unlikely to be evenly distributed between backs,[21,23,24] this may still underestimate the frequency of kicking injuries associated with specific playing positions amongst the backs. In a similar vein, the propensity for injury has also been used to quantify injury frequency for discrete events such as scrummaging and tackling,[14,22] as these calculations directly account for the number of times the given activity is completed. Establishing the frequency of kicking by playing position would therefore enable positional propensity for kicking injuries to be calculated if the playing positions of those players sustaining an injury during kicking were identified. Furthermore, consideration of the typical kicking profiles (i.e. frequency of different types of kick performed) could provide additional valuable information to direct future investigations of the potential mechanisms associated with kicking injuries and identification of potential conditioning and rehabilitation practices for those players most at risk from kicking injuries. The aim of this study was therefore to investigate the epidemiology of injuries directly attributable to kicking in professional rugby, and to consider playing position-specific effects and differences in kicking volumes and kick types.

MATERIALS AND METHODS

Injury epidemiology – data collection

Participants were male, first-team, rugby players contracted to professional clubs competing in the English Premiership or at international representative level for England. Players provided written informed consent for collection and processing of their personal and injury data for research purposes in line with England Rugby's ethical guidelines. The study was approved by the Research Ethics Committee of the academic institution where the Professional Rugby Injury Surveillance Project (PRISP) was hosted for each season.

Injury and exposure data was recorded by medical staff at participating teams as part of the PRISP as outlined in previous studies.[7,8,12,13] The injury diagnoses entered into the PRISP were categorised under the Orchard Sports Injury Classification System (OSICS),[25] and injury definitions were consistent with the international consensus statement on injury surveillance in rugby.[26] Injury data covered 15 seasons from 2002/03 to 2017/18 (2004/05 data were unavailable). Data included all match (Premiership, National Cup, European competition, England internationals) and training injuries from the start of pre-season through to the end of the competitive season.

Data relating to acute-onset injuries which were directly attributed to the act of kicking were extracted. Gradual-onset injuries which may have been caused or exacerbated by the activity of kicking could not be identified from the available data. The data extracted for each kicking injury included: playing position at time of injury; event (match or training); time in match (where applicable); number of days subsequently absent from rugby activity; OSICS code and additional diagnosis information; side injured; dominant limb; and kicking limb. Where kicking limb was not explicitly stated, the dominant limb was assumed to be the kicking limb. Injury data entered prior to the 2013/14 season used three-character OSICS codes, which were converted to the equivalent four-character OSICS codes prior to analysis to ensure consistency with data collected in the subsequent seasons.[25] Injury distribution was initially established by identifying the global body region (e.g. lower limb, upper limb, etc.) from the corresponding OSICS code: injury locations in the pelvis and sacrum, and lower limb, were then further subdivided according to the injury consensus statement.[26] Additional information was gleaned from freehand injury descriptors provided by medical staff when entering injuries into the database, if present. Muscle injuries were limited to the muscle group unless information regarding specific muscles had been identified.

Match kicking characteristics – data collection

All kicks performed during two full seasons of the English Premiership (2016/17 and 2017/18, n = 269 matches; one match unavailable) were coded as part of the formal match analysis undertaken for Premiership Rugby. For each kick, the playing position of the kicker and the type of kick performed (box kick; chip/kick pass; distance punt; drop goal; ground kick (fly hacks and grubbers); hang chase; place kick (from a tee); and restarts (22 m and halfway) were identified (descriptions of each kick type are available in supplementary information; Table S1).

Injury epidemiology – data analysis

Injury incidence calculations were consistent with the international consensus statement.[26] Modified incidence (i.e. using injuries and player-hours for a specific playing position group rather than whole squad data) and injury propensity were calculated in line with previously published methods.[11,14,22,27] For both match and training data, overall incidence and modified incidence (for backs only) were presented as the number of kicking injuries sustained per 1000 player-match-hours or 1000 player-training-hours. All subsequent analyses were based on match data only due to the low incidence of training injuries (see Results). The overall and positional propensity values were determined from all 15 seasons' injury data and both seasons' kick characteristic data, and were calculated as the number of kicking injuries sustained per 1000 kicks. Injury severities were recorded as the total number of days lost, in line with the consensus statement,[26] and reported as median (interquartile range, IQR) values due to the non-normal distribution as determined with Shapiro-Wilk tests ($p < 0.05$). Mean injury severity was also determined in order to calculate the burden (i.e. the product of injury incidence and mean severity) of certain categories of kicking injury.

Match kicking characteristics – data analysis

Mean and standard deviation values were calculated for the number of kicks per match across all 269 matches in the kicking characteristic dataset. Kick type and kick type by playing position were calculated as percentages of this entire dataset and the position-specific subsets (where playing position was reported), respectively. The relative differences between proportions of kick types, and between proportions of kick types completed by each position were established, and were described in a format consistent with previously reported procedures.[28] In brief, these were calculated by subtracting the proportion of kicks in a given kick-type category from that of the distance punts (for kick type) or fly-half (for kick type by position) as the reference values, as these were the categories with the highest counts for each variable. Confidence intervals (CI; 95%) and proportion ratios were calculated for each comparison using the Wilson method.[29] Proportion ratios were calculated by dividing each given proportion by that of the distance punt (for kick type) or fly-half (for kick type by position), with a scale of trivial (1.0), small (1.1), moderate (1.4), large (2.0), very large (3.3) and extremely large (10.0) used to describe the differences.[28] Inverse values were used for negative differences, i.e. 0.9 (small), 0.7 (moderate), 0.5 (large), 0.3 (very large) and 0.1 (extremely large).

For both the kicking injury and kicking volume datasets, if entries did not provide all information, they were only excluded from the specific analysis relating to that piece of information. Where data are absent from calculations, this is acknowledged in the results.

RESULTS

Injury frequency

A total of 134 acute-onset injuries (match: 77 (see Table 1 for positional proportions); training: 55; unspecified: 2) directly attributed to the act of kicking were recorded over the 15 analysed seasons. Across all 15 seasons, total exposures were 116,720 player-match-hours and 1,900,654 player-training-hours. The overall incidence of match kicking injuries was 0.7/1000 player-match-hours and training kicking injuries was 0.03/1000 player-training-hours. Due to the low incidence of training kicking injuries, all subsequent analyses were limited to match data only. Modified match injury incidence for the backs (i.e. 7/15 of the total match exposure and only match injuries sustained by backs), was 1.4/1000 player-match-hours. Over two Premiership seasons, 17,832 kicks were performed (mean ± SD kicks per match = 66 ± 13, range = 38 to 110). Based on a typical English Premiership season of 135 matches, the mean number of kicks during a typical season was calculated (8,949). This was then projected over 15 seasons and applied to the total number of match kicking injuries sustained (77) to yield an overall propensity for match kicking injury of 0.57 injuries per 1000 kicks.

Fly-halves (47%) and full backs (17%) sustained the greatest proportions of match kicking injuries which equates to position-specific injury incidences of 4.6 kicking injuries/1000 player-match-hours for fly-halves and 1.7/1000 player-match-hours for full backs. The positional proportions of all match kicking injuries and the differences between fly-halves and other positional groups are shown in Table 1 (1 out of 77 entries did not specify the playing position at the time of injury).

[**INSERT TABLE 1 NEAR HERE**]

Time of injury in match

A greater number of injuries (n = 14) was sustained during the warm-up period than either the first (n = 7) or second (n = 13) quarters of the game (4 out of 77 entries did not specify time in match). Entries for warm-up injuries did not specify whether players were originally designated as a starter or replacement. Sixty-six percent of all injuries which occurred during the playing time (i.e. 0-80+

minutes) occurred during the second half, and the quarter with the highest proportion of injuries was the third quarter for both starters and replacements (Figure 1).

[**INSERT FIGURE 1 NEAR HERE**]

Injury type and location

Of all match kicking injuries recorded, 92% were located in the pelvis or lower limb (Table 2). Muscle or tendon tissue injury occurred in 82% of these match kicking injuries. In just the pelvis and lower limbs, muscle or tendon injuries accounted for 89% of all match kicking injuries. Of the pelvis and lower limb injuries, 56% were located in the thigh alone. Thigh injuries led to a median severity of 10 days (IQR = 5.0 – 17.8 days; mean: 19.4 days; burden: 6.6 days/1000 player-match-hours) lost from rugby-related activity. Of these, the quadriceps were the most frequently injured muscle group (n = 21, 53%), followed by the hamstrings (n = 13, 33%) and the adductors (n = 6, 15%). The rectus femoris was the most frequently injured individual muscle, sustaining 21% of all match kicking injuries, more than any other individual muscle. Muscle strains accounted for the majority (88%) of thigh injuries, with the remainder being classified as "muscle spasm/tightness/trigger points".

Eighty-one per cent of all pelvis/lower limb match kicking injuries were to the kicking leg side: for thigh injuries alone (i.e. the most commonly injured area), 78% occurred in the kicking limb. Match kicking injuries sustained in the stance limb were more severe (median: 19.5 days, IQR = 4.8 – 44.5 days; mean: 57.7 days) than in the kicking limb (median: 9 days, IQR = 5.0 – 16.3 days; mean: 14.3 days). However, due to the greater number of kicking limb injuries sustained, the mean burden of kicking limb injury (6.3 days/1000 player-match-hours) exceeded that of the stance limb (5.9 days/1000 player-match-hours). Nine of the 77 entries did not provide enough information to determine either the dominant side or kicking limb and were excluded from these analyses.

[**INSERT TABLE 2 NEAR HERE**]

Match kicking characteristics – all players

Of all kicks performed during the two seasons analysed, distance punts were most common (Figure 2). Distance punts were therefore used as the standard for all quantitative comparisons against other kick types (see supplementary information, Table S2). Moderate differences were found between the proportion of distance punts completed and box kicks and restarts. Large differences were found between the proportion of distance punts and place kicks, whilst very large differences were found when compared with the chip/kick pass, ground kicks, and hang chase. Extremely large differences were found between the distance punt and drop goal attempts.

[**INSERT FIGURE 2 NEAR HERE**]

Match kicking volumes - positional differences

Backs performed 99% of all kicks. Five of the 17,832 kick entries did not specify any playing position information and were excluded from all positional group-specific analyses (i.e. backs versus forwards), whilst 84 out of 17,832 kick entries only identified the player as a member of the backs and were subsequently excluded from individual playing position-specific analyses. Fly-halves performed the greatest proportion of total kicks (46%; Figure 3), followed by scrum-halves (27%), full backs (11%), centres (9%) and wingers (6%). The difference between the proportion of kicks completed by the fly-half and scrum-half was moderate, the differences were very large in comparison to centres, wingers and the full back, and extremely large in comparison to forwards (mean differences in proportions and their 95% CIs are presented in supplementary information, Table S3). The position-specific proportions of each kick type with reference to those of the fly-half are presented in Figure 3 (kick type proportion comparisons are also available in supplementary information; Table S4).

[**INSERT FIGURE 3 NEAR HERE**]

Positional propensity for injury

Based on the proportion of match kicks completed by each playing position (Figure 3) and proportion of match kicking injuries sustained, positional propensity for match kicking injury was calculated (Figure 4). Using the categories detailed by Fuller et al.,[14] fly-halves demonstrated an *average* propensity for kicking injury (0.58/1000 kicks), scrum-halves a *very low* propensity (0.17/1000 kicks), and centres (0.85/1000 kicks), full backs (0.86/1000 kicks), wingers (1.22/1000 kicks) and forwards (1.16/1000 kicks) all demonstrated a *high* propensity.

[**INSERT FIGURE 4 NEAR HERE**]

DISCUSSION

This study investigated the epidemiology of injuries directly attributable to kicking in professional rugby, including the consideration of position-specific differences and the potential influence of kicking volumes and kick types. The overall incidence of kicking injuries during matches was 22 times greater than that during training and as such, all subsequent analyses focussed on match injuries. The incidence of match kicking injuries was lower than other injury mechanisms previously reported in rugby. A meta-analysis examining rugby injury epidemiology studies reported that lineouts and scrummaging had the lowest incidences of all reported mechanisms with 1 and 7 injuries per 1000 player-match-hours, respectively.[9] Focussing on kicking injuries is therefore not a priority when considering the overall incidence of injury across the whole squad, with tackle-related injuries clearly a higher priority.[9] However, the importance of considering the injury and task-specific issues associated with each playing position[10] is demonstrated by the greater incidence of kicking injury for the fly-half (4.6/1000 player-match-hours) and full back (1.7/1000 player-match hours). Given the known importance of kicking for match outcome,[2–4] the current results regarding kicking injury epidemiology provide valuable information for the specific physical preparation of players within the squad who frequently kick. These data also provide novel position-specific injury propensity and kick type information which can be used to inform technical, tactical and physical preparation profiles, as well as to inform decisions regarding the return on investment associated with position-specific interventions intended to reduce the risk of injury.[20]

Modification of injury incidence to only include a specific positional group can be more informative than calculations based on an entire team.[22] As backs performed 99% of all kicks in the current study, a modified calculation for kicking injury incidence was limited to the match injuries sustained by backs and their associated exposure hours. However, this modified incidence (1.4/1000 player-match-hours) still assumes that all backs are equally exposed to a potentially injurious mechanism, which is clearly not the case (Figures 3 and 4). Propensity for injury provides a more appropriate method of reporting injury frequency, particularly when sub-divided by playing positions.[14,22] The overall propensity for injury due to kicking (0.57/1000 kicks) was lower than that of other match events reported previously (1.1/1000 lineouts; 2.0/1000 rucks).[16] However, a greater number of players are exposed to a potential injury mechanism in each lineout or ruck than in a single kick. Furthermore, when considered by playing position groups (Figure 4), there is not a linear relationship between the proportion of match kicks performed and the number of kicking injuries sustained. Consistent with a previous study of international rugby,[21] the fly-half performs the highest volume of match kicking (46%). The fly-half also sustains the greatest proportion of kicking injuries (47%), and thus has an *average* propensity for kicking injury.[14] Whilst scrum-halves perform almost a quarter of all kicks, their kicking injury propensity (0.17/1000 kicks) is *very low*, whereas the wingers, centres, full backs and forwards all have a *high* propensity for kicking injury (Figure 4). The propensity for kicking injury therefore appears to be affected by other position-specific factors rather than simply exposure to kicking.

Whilst specific physical preparation and exposure to kicking during training are potential factors which could influence position-specific propensity for match kicking injury, these would likely not explain the observed differences between fly-halves and scrum-halves. The type of kick undertaken may also be an important consideration because there are numerous types performed, each of which may place varying demands on the kicker. Given the apparent differences in kick types performed between scrum-halves (i.e. box kicks constituting almost 70% of a scrum-half's total kicking load, Figure 3) and the other playing positions who all exhibit higher propensities for kicking injury, it is possible that the mechanics of a box kick are potentially less injurious than other kick types. However, caution must be applied because whilst the mechanics of goal kicking[30–33] and punt kicking[34–36] have previously been studied in both rugby and Australian Rules Football, direct comparisons between kick type mechanics have not been undertaken and there have been no mechanical descriptions of the other rugby kick types included in the current study. Furthermore, the studies examining goal or punt kicking have focussed on identifying variables which are associated with successful performance, rather than the potential role of kicking mechanics in injury. Given this lack of research, it is challenging to make inferences regarding the potential for injury potential based on specific kick types. Direct comparisons of the mechanics of different kick types may provide useful biomechanical information which can be used to investigate the demands placed on the musculoskeletal system and shed light on the potential role of kick type as an injury risk factor.

The time in the match is also a factor of importance when considering rugby injuries. Two-thirds of all match kicking injuries which occurred during the playing time (i.e. 0-80+ minutes) were in the second half, with the third quarter the most injurious for both starters and replacements. This is consistent across the pooled rugby literature,[9] and may be related to decrements in technique associated with fatigue in starters, as seen in other rugby-specific tasks such as tackling.[37] However, those observed technique decrements[37] were found to be mitigated by physical characteristics such as increased strength, demonstrating that task-specific physical preparation may be an important consideration. Incomplete warm-ups prior to the second half may also contribute to the increased frequency of injuries seen in the third quarter,[38] which may affect both starters and replacements. The incidence of match kicking injuries also included warm-up injuries as this directly involved the match squad and preparation outside of training hours. However, as the total exposures of warm-ups were unknown, this may therefore overestimate the incidence of match injuries. It is worth noting that the number of warm-up injuries exceeded those sustained in either the first or second quarters of the match. Whilst the reason for this cannot be determined from the current analysis, kickers anecdotally perform a high volume of kicks in a relatively short space of time during a warm-up. Medical and performance staff may therefore need to consider the approach to kicking used in the warm-up if players are sustaining injury during a controlled period which is intended to prepare them for match play.

Consistent with previous rugby-based epidemiology studies,[9] the majority of kicking injuries were located in the pelvis or lower limb, with 81% of these occurring in the kicking limb. The median severity of stance limb kicking injuries was higher than that of the kicking limb, but the greater frequency of kicking limb injuries meant that the overall burden of kicking and stance limb injuries was similar (6.3 and 5.9 days/1000 player-match-hours, respectively), even despite two stance limb injuries with severities in excess of 100 days being sustained. The thigh was the most injured segment, and 84% of injuries in this location were muscular strains. Rectus femoris sustained more kicking injuries than all other specific locations and accounted for 21% of all match kicking injuries. This was followed by muscular strains in the hamstrings and adductors. In soccer-specific studies, the rectus femoris has been implicated in up to 48% of hip flexor-specific MRI assessments.[39] Given the relative similarity in the prevalence of anterior thigh muscle injuries in a kicking-dominant sport such as soccer and the kicking-specific rugby injuries in the current study, this suggests that anterior thigh strains, in particular to the rectus femoris, should be a primary focus when working with rugby players who are expected to kick.

The epidemiological data presented in the current study were obtained prospectively over multiple seasons. As the analysis of kick counts and types was only available for the two most recent domestic Premiership seasons, these were used to estimate the propensity for kicking injury sustained during Premiership and England matches across all seasons in which injury epidemiological data were recorded. It is possible that total kick counts could change over seasons (e.g. due to style of play or law changes) and between levels of play (i.e. domestic versus international). It was not possible to assess this in the current study given that kick count and type data were only available over two seasons, and future prospective analyses could be undertaken to assess these potential changes in kicking patterns. Future work could also seek to document the type of kick performed (and other situational factors) at the time of each kicking injury, as these data were also not available in the current study and could provide a clearer picture of which kick types lead to the greatest onset of injury. It is also worth noting that the estimates of kicking injury frequency in the current study may be conservative. It was only possible to extract acute-onset kicking injuries from the dataset and, as such, gradual-onset injuries which were caused or exacerbated by repeated kicking are excluded. It is currently unknown how kicking volumes may contribute to accumulated match fatigue and injuries classified as occurring during another match event, and vice versa. As such, it may be beneficial to investigate all injuries sustained by kickers in order to truly understand the position-specific problems, although this is clearly not without its challenges, due to the multi-factorial nature of injury risk.

CONCLUSION

This is the first study to investigate the epidemiology of kicking-related injuries in professional Rugby Union with this level of detail, and the first to present a breakdown of position-specific kick types over multiple seasons. Kicking injuries are most commonly sustained in the pelvic region and lower limbs, with muscular strains being the most common injury diagnosis, particularly of the kicking limb rectus femoris. Traditional incidence of kicking-related injuries is low in comparison to other mechanisms of injury, however, clear position-specific factors have been identified. The fly-half sustains the most injuries from kicking with an *average* propensity, scrum-halves have a *very low* propensity for kicking injury, and forwards and other backs have a *high* propensity for kicking injury. Time in match affects the incidence of kicking injury with the majority of kicking injuries being sustained in the second half and during the warm-up.

PERSPECTIVE

Practitioners are advised to consider the current findings when incorporating kicking into position-specific training and conditioning programmes due to the differences demonstrated between playing positions in both propensity and match kicking characteristics, and these should also be considered in warm-up preparations prior to matches. It may be that specific preparation for kicking (e.g. during training) and other factors such as the type of kick performed may influence the observed differences in propensity, however further research is required to directly investigate this. Further research is also needed to better understand the potential mechanisms for kicking thigh muscle strain injuries, potentially across the different kick types, as well as to explore whether continued exposure to kicking may influence the occurrence of other gradual-onset injuries.

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TABLES

Table 1. Proportion of total number of match kicking injuries sustained per positional group. Differences are presented relative to the Fly-half as the position which sustained the highest proportion of injuries.

Playing Position	Proportion (%)	Difference (%)	95% CI	Proportion Ratio	Qualitative Inference
Forwards	2.6	-44.7	-56.0 – -32.1	0.1	Extremely Large
Scrum-half	7.9	-39.5	-51.3 – -25.9	0.2	Very Large
Fly-half	47.4	–	–	–	–
Wingers	11.8	-35.5	-47.9 – -21.4	0.3	Very Large
Centres	13.2	-34.2	-46.7 – -19.9	0.3	Very Large
Full Back	17.1	-30.3	-43.3 – -15.5	0.4	Large

95% CI = 95% confidence interval

Table 2. Number of match kicking injuries by location and type.

Injury	Upper Limb	Trunk	Pelvis and Lower Limb	All
Fractures/Bone Stress	0	0	1	1
Joint (non-bone)/Ligament	2	1	7	10
Muscle/Tendon	1	1	63	65
Central/Peripheral Nervous System	1	0	0	1
All	4	2	71	77

FIGURES

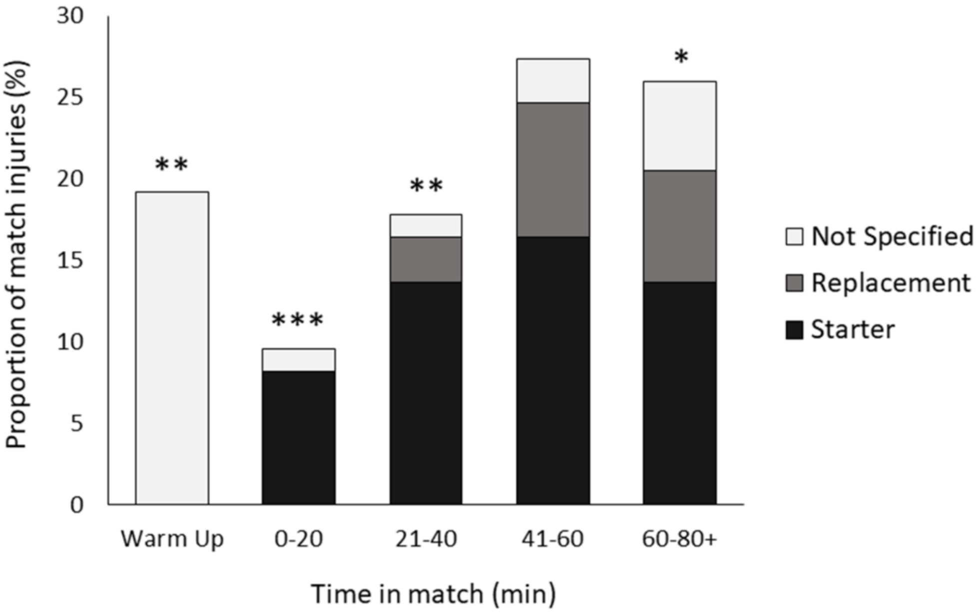

Figure 1. Time in match split by starter or replacement. * = Trivial difference in overall proportion versus 41-60 min. ** = Moderate difference in overall proportion versus 41-60 min. *** = Large difference in overall proportion versus 41-60 min.

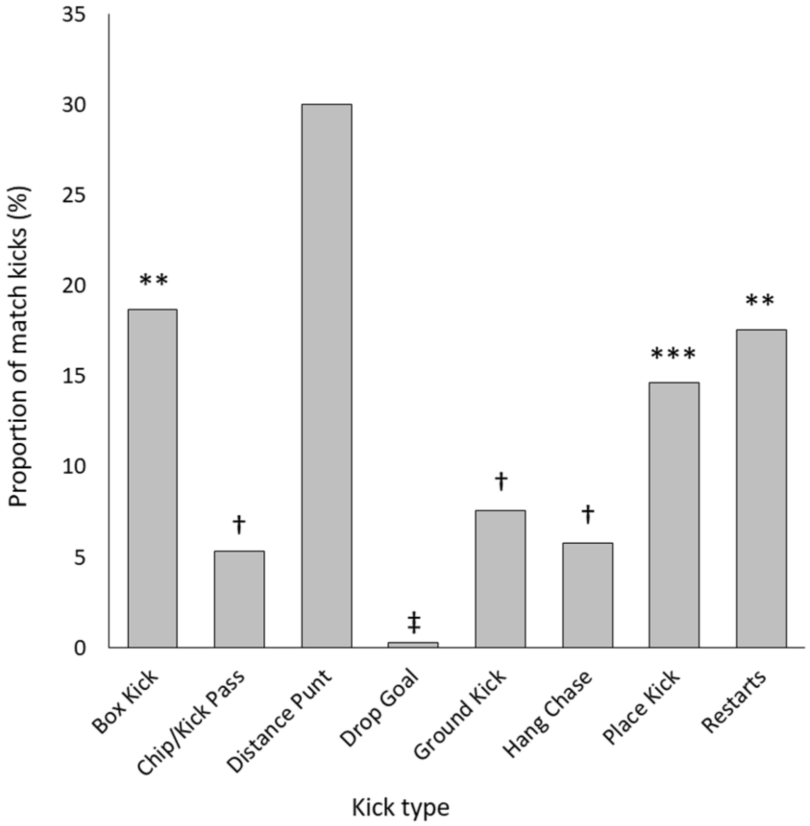

Figure 2. Proportion of each match kick type completed. ** = Moderate difference in proportion versus Distance Punt. *** = Large difference in proportion versus Distance Punt. †= Very Large difference in proportion versus Distance Punt. ‡ = Extremely Large difference in proportion versus Distance Punt.

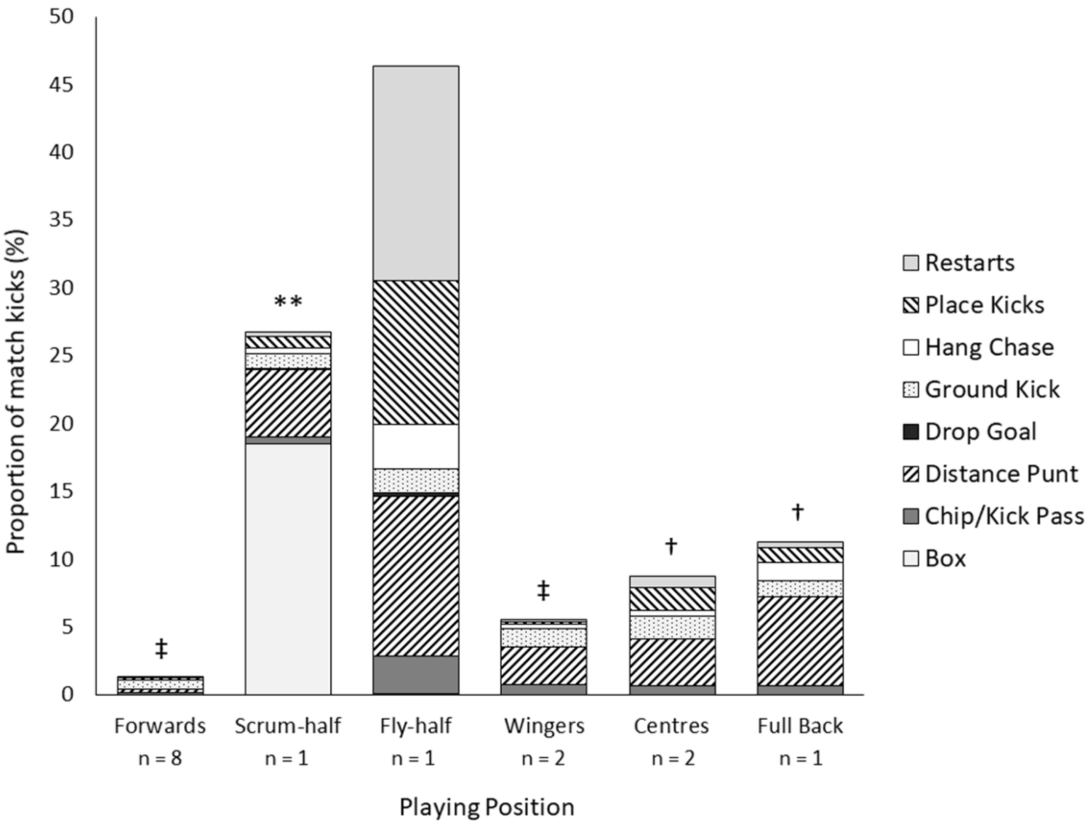

Figure 3. Proportion of kicks completed by playing position, subdivided by kick type. Number of players included in each position shown, with total number of kicks taken by all players in forward, wing and centre position included in these categories. ** = Moderate difference in overall proportion versus Fly-half. † = Very Large difference in overall proportion versus Fly-half. ‡ = Extremely Large difference in overall proportion versus Fly-half.

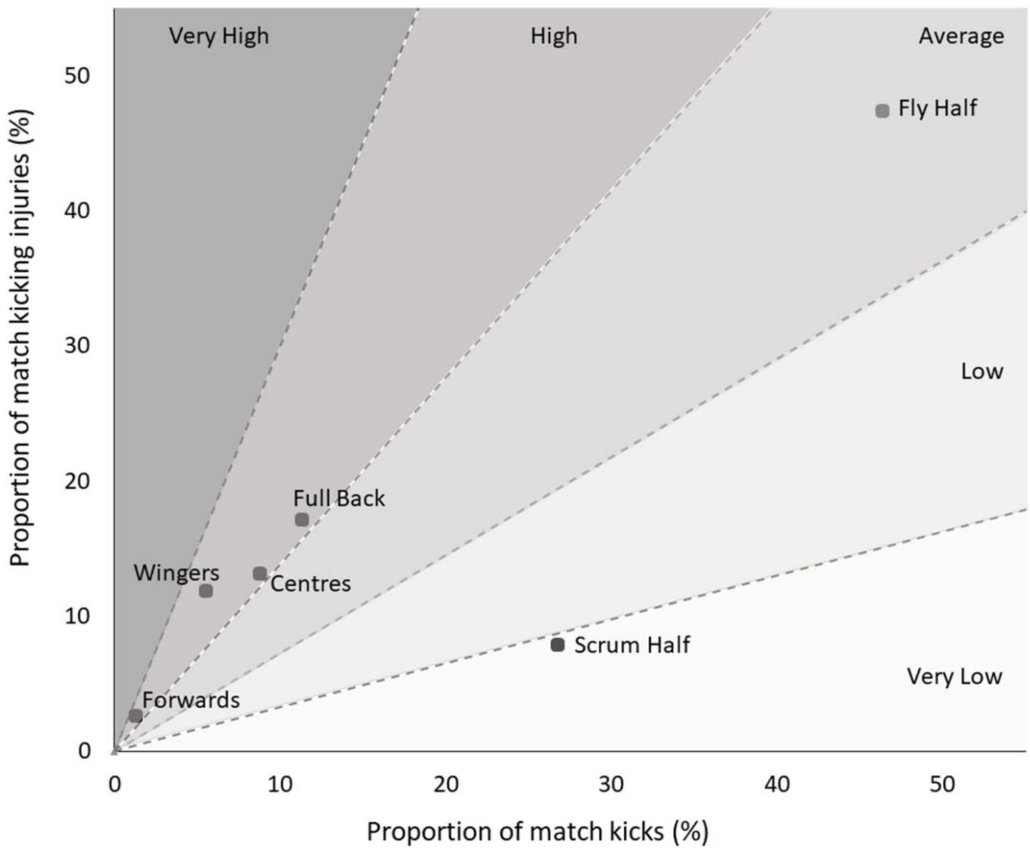

Figure 4. Relative propensities of match kicking injuries by playing position.

Supplementary information

Table S1. Descriptions of each kick type category included in the current analysis.

Kick type category	Brief description
Box kick	A clearance kick from hand (typically for height and distance) performed directly behind a ruck, scrum or lineout
Chip / kick pass	A sub-maximal kick from hand with the aim of regathering the ball / a sub-maximal kick from hand with the aim of delivering the ball to a teammate
Distance punt	A maximal distance kick from hand with the aim of achieving touch, a territory gain, or the relief of defensive pressure
Drop goal*	An attempt at goal with the ball dropped from hand during a passage of open play
Ground kick (fly hack / grubber)	A kick along the ground when the ball is not in hand / a low kick from hand along the ground
Hang chase	A kick primarily for height rather than distance, with the aim regaining possession
Place kick (conversion or penalty)	An attempt at the goal posts from a kicking tee after a try is scored or as an option after a penalty is awarded
Restart* (22 m / halfway)	A drop kick behind the defending 22 m line to restart the match after the ball has been grounded by a defending player within the 'in-goal' area / a drop kick on the halfway line to either start the match at the beginning of a half, or to restart the match following a try

** Restarts were separated from drop goals because they are self-paced rather than being under the more dynamic constraints of open play, and they are also typically performed with a greater requirement for height.*

Table S2. Proportion of kicks completed by kick type.

	Proportion of total kicks (%)	Versus Distance Punt			
		Difference (%)	95% CI	Proportion Ratio	Qualitative Inference
Box	18.7	-11.4	-12.3 – -10.5	0.62	Moderate
Chip/Kick Pass	5.4	-24.7	-25.4 – -23.9	0.18	Very Large
Distance Punt	30.0	–	–	–	–
Drop Goal	0.3	-29.7	-30.4 – -29.1	0.01	Extremely Large
Ground Kick	7.6	-22.4	-23.2 – -21.7	0.25	Very Large
Hang Chase	5.8	-24.2	-24.9 – -23.5	0.19	Very Large
Place Kick	14.6	-15.4	-16.3 – -14.6	0.49	Large
Restarts	17.6	-12.4	-13.3 – -11.6	0.59	Moderate

95% CI = 95% confidence interval.

Table S3. Proportion of kicks completed by playing position.

	Proportion of total kicks (%)	Versus Fly Half			
		Difference (%)	95% CI	Proportion Ratio	Qualitative Inference
Forwards	1.3	-45.1	-45.8 – -44.3	0.03	Extremely Large
Scrum Half	26.8	-19.6	-20.6 – -18.6	0.58	Moderate
Fly Half	46.4	–	–	–	–
Wingers	5.5	-40.8	-41.6 – -40.0	0.12	Very Large
Centres	8.8	-37.6	-38.4 – -36.7	0.19	Very Large
Full Back	11.3	-35.1	-35.9 – -34.2	0.24	Very Large

95% CI = 95% confidence interval.

Table S4. Proportion of total number of kicks completed per positional group split by kick type.

		Proportion of position-specific total kicks (%)	Versus Fly Half			
			Difference (%)	95% CI	Proportion Ratio	Qualitative Inference
Box	Forwards	3.0	2.9	1.3 – 6.0	20.86	Extremely Large
	Scrum Half	69.3	69.1	67.8 – 70.4	474.94	Extremely Large
	Fly Half	0.1	–	–	–	–
	Wingers	0.1	-0.04	-0.2 – 0.4	0.70	Moderate
	Centres	0.2	0.05	-0.1 – 0.4	1.32	Small
	Full Back	0.3	0.2	-0.04 – 0.5	2.06	Large
Chip/Kick	Forwards	7.4	1.4	-1.4 – 5.5	1.23	Small
	Scrum Half	1.7	-4.3	-5.0 – -3.7	0.28	Very Large
	Fly Half	6.0	–	–	–	–
	Wingers	14.0	7.9	5.9 – 10.3	2.32	Large
	Centres	7.3	1.2	-0.05 – 2.7	1.21	Small
	Full Back	5.6	-0.4	-1.5 – 0.8	0.93	Trivial
Distance Punt	Forwards	24.8	-0.7	-6 – 5.3	0.97	Trivial
	Scrum Half	18.8	-6.8	-8.2 – -5.3	0.74	Small
	Fly Half	25.5	–	–	–	–
	Wingers	50.5	25.0	21.7 – 28.3	1.98	Moderate
	Centres	39.4	13.9	11.3 – 16.5	1.54	Moderate
	Full Back	58.5	33.0	30.6 – 35.3	2.29	Large
Drop Goal	Forwards	0.0	-0.5	–	–	–
	Scrum Half	0.1	-0.4	-0.6 – -0.25	0.13	Very Large
	Fly Half	0.5	–	–	–	–
	Wingers	0.0	-0.5	–	–	–
	Centres	0.4	-0.04	-0.33 – 0.46	0.92	Trivial
	Full Back	0.1	-0.4	-0.6 – -0.1	0.21	Very Large
Ground Kicks	Forwards	47.8	43.9	37.6 – 50.4	12.29	Extremely Large
	Scrum Half	4.1	0.2	-0.5 – 0.9	1.05	Trivial
	Fly Half	3.9	–	–	–	–
	Wingers	24.0	20.1	17.5 – 22.9	6.18	Very Large
	Centres	18.5	14.6	12.7 – 16.6	4.75	Very Large
	Full Back	10.0	6.2	4.8 – 7.6	2.58	Large
Hang Chase	Forwards	1.3	-5.6	-6.6 – -3.1	0.19	Very Large
	Scrum Half	1.7	-5.2	-5.9 – -4.6	0.24	Very Large
	Fly Half	6.9	–	–	–	–
	Wingers	5.4	-1.5	-2.9 – 0.2	0.78	Small
	Centres	5.2	-1.7	-2.9 – -0.4	0.75	Small
	Full Back	12.3	5.4	3.9 – 7.0	1.78	Moderate
Place Kicks	Forwards	10.4	-12.5	-15.9 – -7.8	0.46	Large
	Scrum Half	3.3	-19.6	-20.6 – -18.5	0.14	Very Large
	Fly Half	22.9	–	–	–	–
	Wingers	4.1	-18.8	-20.2 – -17.1	0.18	Very Large
	Centres	19.2	-3.7	-5.8 – -1.5	0.84	Small
	Full Back	9.5	-13.4	-14.9 – -11.8	0.41	Large
Restarts	Forwards	5.2	-28.9	-31.4 – -25.1	0.15	Very Large
	Scrum Half	1.1	-33.0	-34.1 – -31.9	0.03	Extremely Large
	Fly Half	34.1	–	–	–	–
	Wingers	1.9	-32.2	-33.5 – -30.7	0.06	Extremely Large
	Centres	9.8	-24.3	-26.1 – -22.5	0.29	Very Large
	Full Back	3.7	-30.4	-31.7 – -29.1	0.11	Very Large

95% CI = 95% confidence interval.