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The incidence and mechanism of heading in European professional football players over three seasons

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Abstract

There are concerns surrounding the risk of neurodegenerative diseases associated with football (soccer) heading. The aim of this study was to conduct analysis on the incidence and mechanism of heading in the "Big 5" professional European football leagues (Bundesliga, Ligue 1, Premier League, La Liga and Serie A) and one lower tier professional league (English Championship) from 2016/17-2018/19. Match event data from 7147 matches were obtained from Opta Sports data feed. The data were parsed to extract header event details including player position, coordinates on the field, header type and preceding match event (including distance football travelled). Incidence data were reported as headers per match or match headers per player. Medians and interquartile ranges (IQR) were reported and either the Mann-Whitney U-Test or Kruskal-Wallis test were conducted for comparisons between positions and leagues. In the "Big 5" leagues, the most headers per match occurred during the Premier League (111.2 headers per match). However, the lower tier English Championship had the highest number of headers per match overall (139.0 headers per match). In all leagues, defenders had the greatest median number of match headers per player ($p<0.001$). The highest median distance travelled by the football during a preceding match event was for goal kicks (57.5 m; IQR 53.7-61.1). The findings add necessary information for current longitudinal studies aiming to understand the potential link between football heading and neurodegenerative diseases. These studies should account for league, playing position and level of play.

1. Introduction

There are concerns surrounding the risk of neurodegenerative diseases associated with football (soccer) heading with the majority of research resulting in methodological shortcomings, contradictory or inconclusive findings.[1-4] The concerns of short and long-term health consequences from football heading could prevent the population from participating in football, which in turn, could have adverse knock on effects for public health.[1] To combat this, the Football Association delivered new guidance on heading in youth football training.[5] No heading in primary school age pupils and a graduated approach to heading in children aged between 12 and 16 during training was advised.[5] A recent study found that these policy changes could be further enhanced by replacing goal kicks which result in the highest heading ball speeds, and hence greatest head contact forces, with throws or head-height rules at certain age grades as part of a phased introduction to heading.[6] Many studies reconstruct football headers in a laboratory environment to measure acute clinical changes.[7,8] The studies often select header numbers and laboratory conditions (e.g. football speeds and distance travelled) lacking in real-world evidence for the reconstructions. Reconstructions more representative of match demands may be more appropriate, however the data is currently lacking at the top European level.

A recent systematic review, found that there is insufficient evidence to either support or refute the potential of effects from acute heading exposure in youth and young adult football players.[9] Kontos et al.[2] conducted a meta-analytical review on football heading effects on neurocognitive performance, cognition and symptom reports which indicated no overall effect for heading a football on adverse outcomes. However, age was identified as the only potential moderating variable.[2] A systematic review found various methodological shortcomings which limit the evidence for persistent effects of football play on brain structure/function.[4] A high profile large retrospective cohort study was recently undertaken by Mackay et al.[3] comparing mortality from neurodegenerative disease among former professional football players with that among matched controls from the general population. Former professional football players had a higher estimated risk of death with neurodegenerative disease listed as a primary or contributory cause.[3]

Heading incidence was not quantified by Mackay et al.[3] and there is limited data on the incidence rate of heading in football, particularly in the professional game. Studies have attempted this through video analysis of a subset of games[10,11] and/or wearable skin-patch sensors.[12] Dellal et al.[13] compared match performance in professional football players across the Spanish La Liga and English Premier League by analysing a total of 600 matches using a multiple-camera match analysis system. Dellal et al.[13] found average total heading duels (one-on-one situations in which players were competing for possession) to range from 6.7-18.5 and 2.5-6.3 in the Premier League and La Liga, respectively, based on playing position. Sandmo et al.[10] found that headers per match increased with age up to senior level. From video analysis of 10 Norwegian premier leagues matches, the average total headers per match was 112.7 and 88.6 in the male and female league, respectively.[10] Beaudouin et al.[11] assessed heading incidence in youth football in eight European countries and found that under-10 teams executed the lowest average number of headers per match (8.8 headers per team), followed by Under-16 female (17.7 headers per team), Under-12 (18.4 headers per team), and Under-16 male (35.5 headers per team).

Analysis of the incidence and mechanism of heading in professional football is needed to understand the extent of the relationships between heading and potential risks of neurodegenerative diseases. The analysis would be beneficial for guiding policy changes aiming to reduce the incidence and/or severity of a given header impact. Additionally, the provision of quantitative data from match analysis on heading incidence would help with current longitudinal studies aiming to understand the potential link between football heading and neurodegenerative diseases as well as studies reconstructing football headers in a laboratory environment. The aim of this study was to conduct analysis on the incidence and mechanism of heading in the "Big 5" professional European leagues (Bundesliga, Ligue 1, Premier League, La Liga and Serie A) and one lower tier professional league (English Championship) over three seasons from 2016/17-2018/19.

2. Methods

2.1. Data collection

A total of 7147 matches from the 2016/17-2018/19 seasons of the "Big 5" leagues and English Championship was obtained from Opta Sports (https://www.optasports.com/). Opta Sports provide live

feeds of match events including details and full x,y location coordinates for every on-ball event. Every possible type of ball actions in a match is covered and recorded in the Opta Sports system.[14] Each game is analysed live by 3 analysts: two main analysts code events for their respective team whilst a checker analyst checks their data in real-time. Once the game is completed, the data is sent to a post-match analyst, who goes through the entire game to ensure each data point is correct, including the location on the pitch, the player and the action. Only the highest performing analysts are assigned to "Big 5" or Championship matches. The data from the post-match analyst were used for the purpose of this study. The data were brought through on a match level (with pseudo-ID) and no personal data were obtained. Therefore, ethical permission was not required similar to other match analysis studies.[13,15]

Each match from the 2016/17-2018/19 seasons of the "Big 5" leagues and English Championship were retrieved using the Opta provided interface and data feed. The feed was parsed to extract match events which correspond with the ball being headed. The event details were noted including player position, coordinates on the field, header type (clearance, flick on, interception, pass or shot) as well as the details of the preceding match event (chipped, clearance, corner, cross, goal kick, headed pass, long ball, pass, throw in). The total number of playing positions per match accounted for substitutions and formation changes. For example, if a player played half of a match as a defender and was replaced for the remaining half by a midfielder, both players would contribute 0.5 to the defender and midfielder positions for the match. The total number of playing positions per match therefore always summed to 22. By utilising the relative x, y coordinates (provided by Opta as being between 0 to 100% of the pitch length/width) of the header event and the preceding match event, the distance travelled by the football was approximated using the average size of a Premiership pitch (103.4m by 67.6m).[16] This data were then used to populate a MySQL database table. SQL queries were executed to extract relevant sub-tables for statistical analysis.

2.2. Statistical analysis

Incidence data were reported as headers per match or match headers per player (i.e. headers per player per match).[10] A Kolmogorov-Smirnov test indicated that the data were non-parametric. Therefore, medians and interquartile ranges (IQR) were reported and either the Mann-Whitney U-Test or Kruskal-

Wallis test were conducted for comparisons between positions, leagues and distances with significance values adjusted by the Bonferroni correction for multiple tests for pairwise post hoc analysis.[17] SPSS version 25 (IBM SPSS Statistics, IBM Corporation) was used for all statistical analyses.

3. Results

Out of the "Big 5" leagues, the most headers per match occurred during the Premier League (111.2 headers per match; 95% CI 109.6-112.7), followed by the Bundesliga (108.4 headers per match; 95% CI 106.6-110.2), La Liga (98.6 headers per match; 95% CI 96.9-100.3), Ligue 1 (93.7 headers per match; 95% CI 92.2-95.2) and Serie A (92.2 headers per match; 95% CI 90.8-93.5). Overall, the Championship had the highest number of headers per match (139.0 headers per match; 95% CI 137.4-140.7).

In all leagues, defenders had the greatest number of match headers per player (Figure 1). Overall, goalkeepers had <0.05 headers per match, and thus no further analysis was conducted for this position. Most defender and midfielder headers were passes (57.4-68.3%) to another player, whilst most forward headers were a pass (35.7-43.7%) or flick on (37.6-47.0%) depending on the league (Figure 1). The Championship had the highest number of match headers per player for all positions (Figure 1&2). Out of the "Big 5" leagues, the Premier League had the highest number of match headers per player for defenders and forwards whilst the Bundesliga had the highest number of match headers per player for midfielders (Figure 1&2). Tabulated results of Figure 1 and 2 can be found in Appendix A.

The preceding match event for most defender and forward headers was a long ball (35.1-51.0%), whilst for midfielders it was a long ball (27.0-32.1%) or headed pass (18.9-29.5%) depending on the league (Figure 2). Goal kicks accounted for 5.7-7.9% of headers for defender, 8.7-11.5% for forwards and 6.1-10.8% for midfielders depending on the league. The highest median distance travelled by the football during a preceding match event was for a goal kick (Median 57.5 m; IQR 53.7-61.1), followed by a long ball (Median 39.8 m; IQR 34.9-44.3) and a corner (Median 32.2 m; IQR 28.0-35.6) (Figure 3). All-pairwise comparison adjusted p-values were <0.001 for distance travelled during preceding match events.

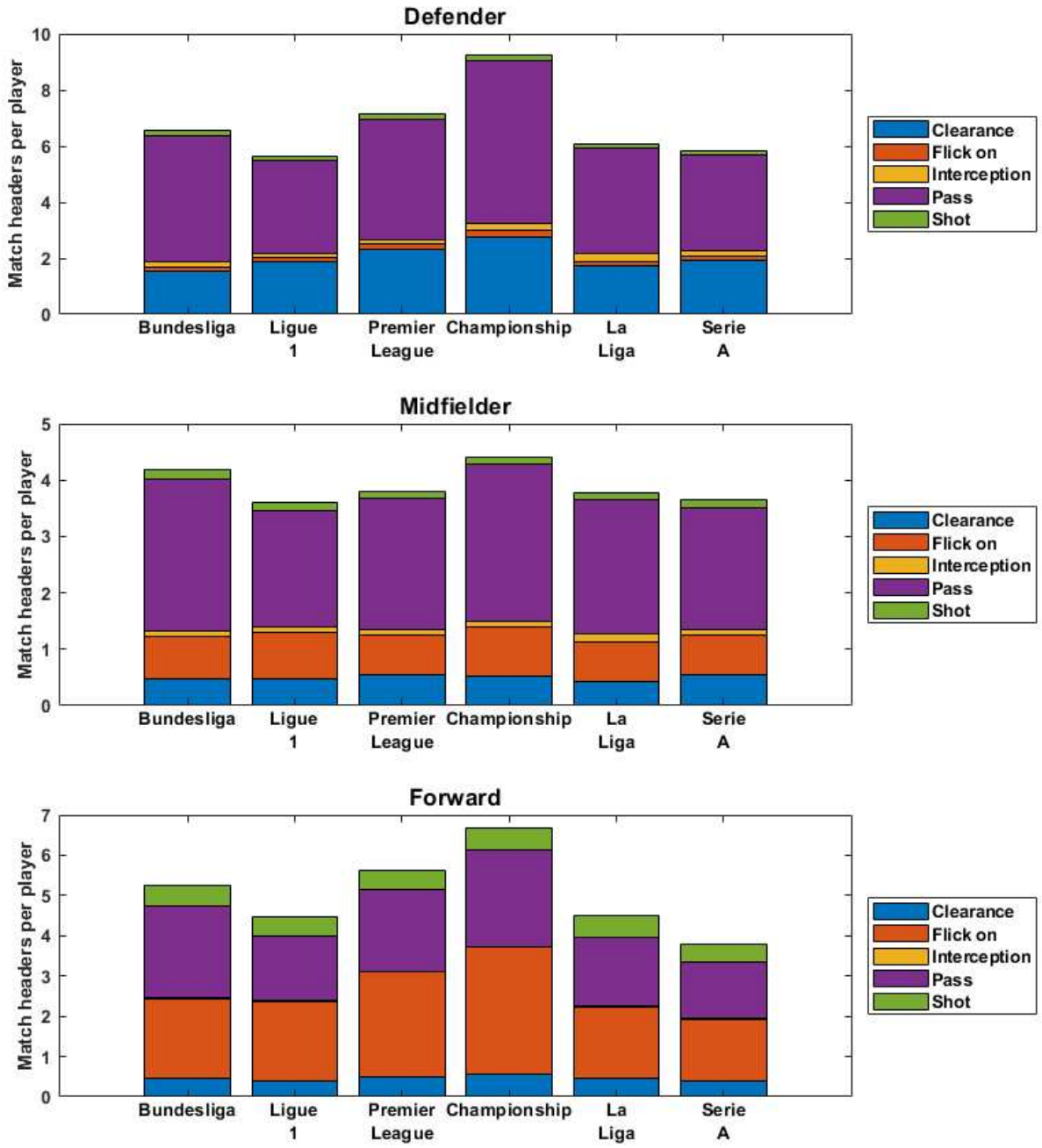

Figure 1. Match headers per player based on header type, league and position.

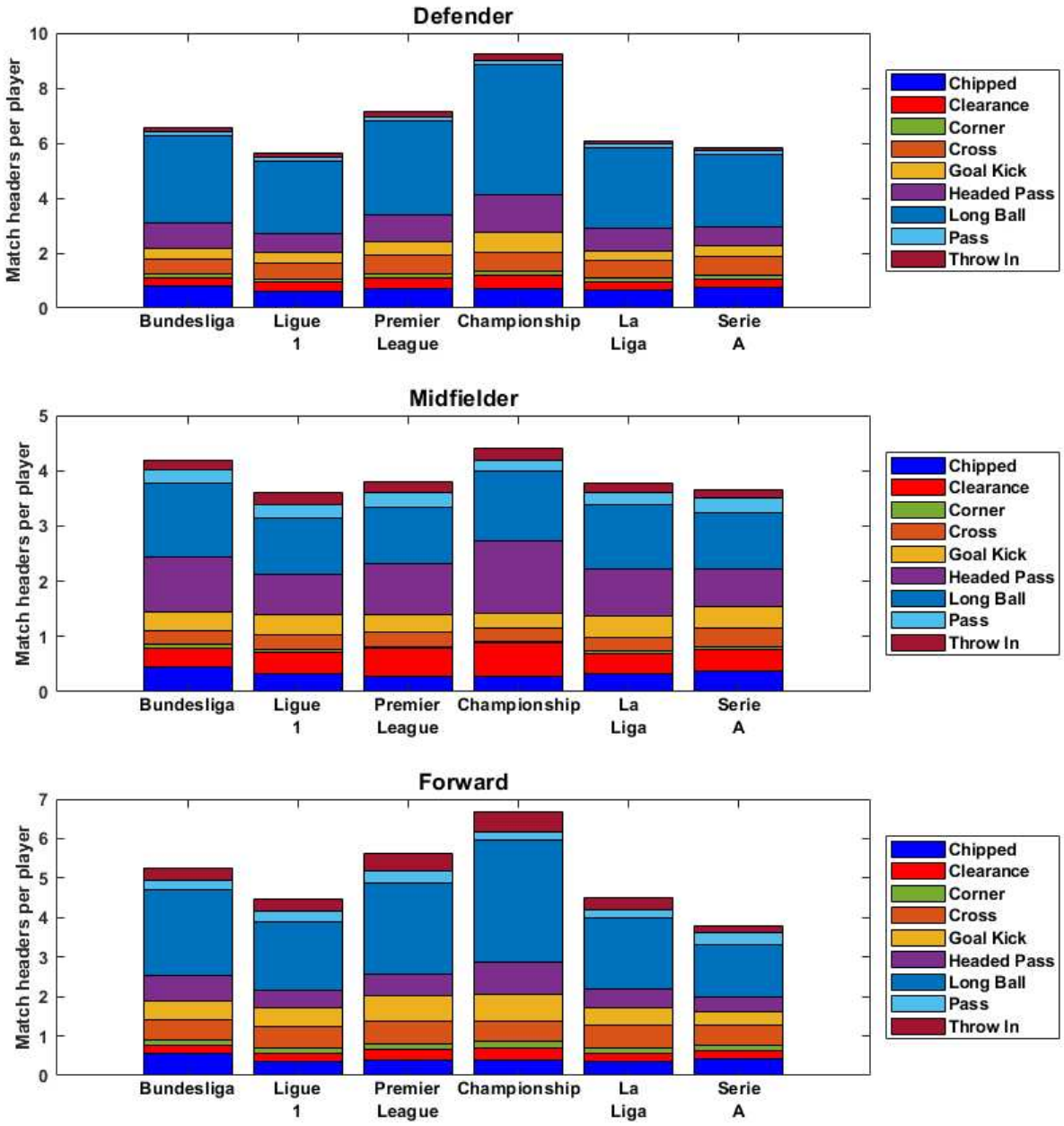

Figure 2. Match headers per player based on preceding match event, league and position.

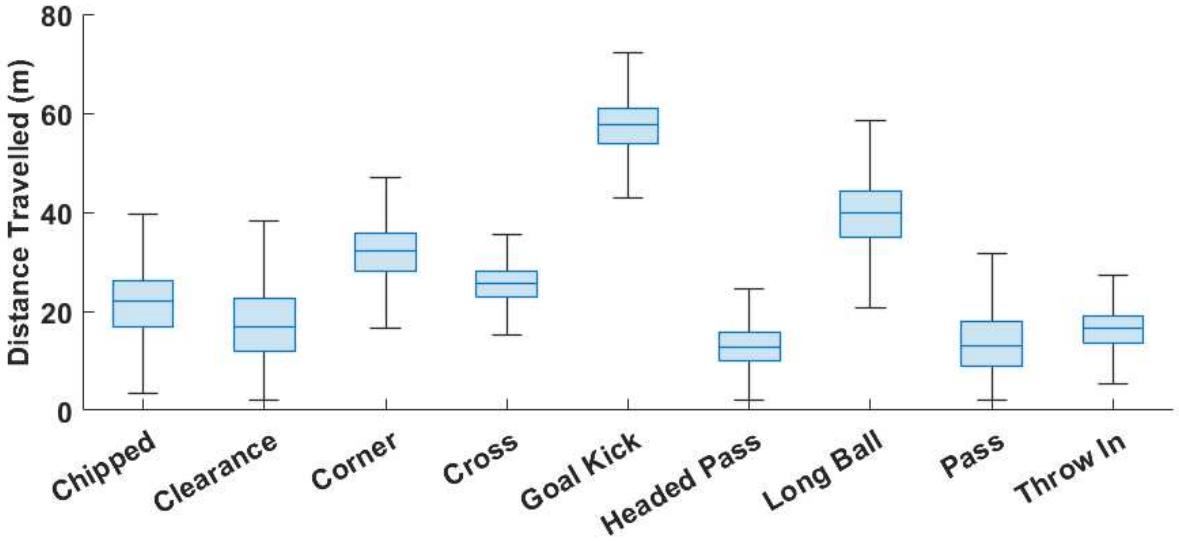

Figure 3. Median distance (with quartiles and range) travelled by the ball based on preceding event type. All-pairwise comparison adjusted p-values were <0.001.

The median number of match headers per player was highest for defenders (Median 6.1; IQR 4.9-7.4), followed by forwards (Median 4.3; IQR 3.0-6.0) and midfielders (Median 3.7; IQR 2.8-4.6) in the "Big 5" leagues (Figure 4). All-pairwise comparison adjusted p-values were <0.001. Outlier values reached up to 19.7 match headers per player for forwards (Figure 4). For the "Big 5" leagues, the Premier League had the highest median number of match headers per player for defenders ($p<0.001$) and forwards ($p<0.001$) whilst the Bundesliga had the highest number of match headers per player for midfielders ($p<0.001$) (Table 1).

All-pairwise comparison adjusted p-values were <0.001 except for Ligue 1-Serie A ($p=0.147$) and Serie A-La Liga ($p=0.029$) for defenders, Bundesliga-Premier League ($p=0.217$) and La Liga-Ligue 1 ($p=0.827$) for forwards, and Serie A-Premier League ($p=0.046$), Serie A-La Liga ($p=0.448$), Ligue 1-Serie A($p=0.198$) and La Liga-Premier League ($p=0.410$) for midfielders. All positions had greater median match headers per player ($p<0.001$) in the Championship when compared to the higher tier Premier League (Table 2).

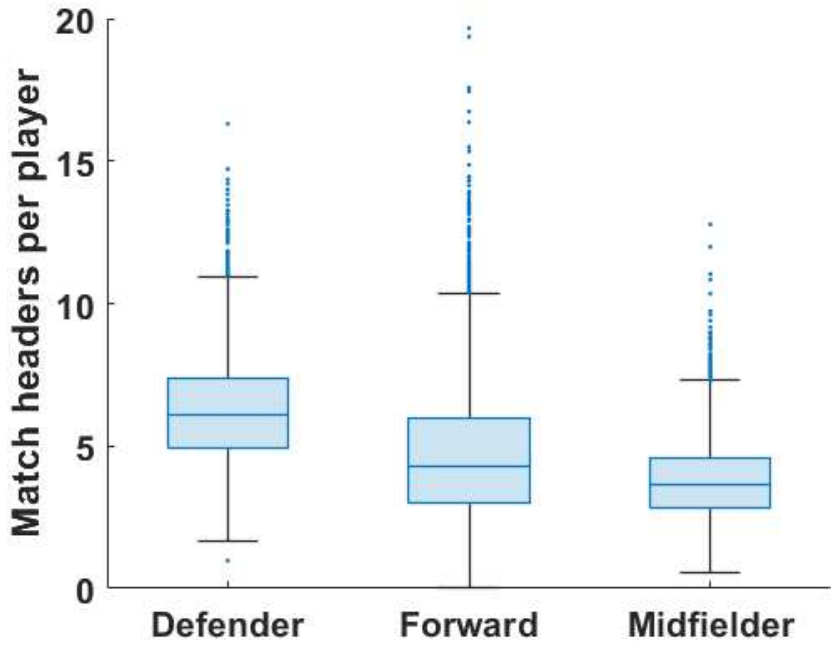

Figure 4. Median number (with quartiles and outliers) of match headers per player based on position from the Big 5 leagues. All-pairwise comparison adjusted p-values were <0.001.

Table 1. Median number (with quartiles) of match headers per player based on position and league for the "Big 5" leagues.

	Bundesliga	Ligue 1	Premier League	La Liga	Serie A	p-value
Defender	6.39 (5.37-7.66)	5.57 (4.53-6.70)	6.98 (5.84-8.25)	5.92 (4.71-7.26)	5.69 (4.71-6.83)	<0.001
Midfielder	4.03 (3.13-5.01)	3.44 (2.61-4.41)	3.65 (2.94-4.54)	3.67 (2.71-4.68)	3.51 (2.76-4.38)	<0.001
Forward	4.98 (3.69-6.52)	4.13 (2.98-5.72)	5.12 (3.62-7.18)	4.11 (2.87-5.71)	3.51 (2.58-4.74)	<0.001

Table 2. Median number (with quartiles) of match headers per player based on position for the Premier League and Championship.

	Premier League	Championship	p-value
Defender	6.98 (5.84-8.25)	9.00 (7.43-10.90)	<0.001
Midfielder	3.65 (2.94-4.54)	4.24 (3.30-5.26)	<0.001
Forward	5.12 (3.62-7.18)	6.29 (4.36-8.54)	<0.001

4. Discussion

A large match dataset (n=7147 matches) was used to conduct analysis on the incidence and mechanism of heading in the "Big 5" professional European leagues and a lower tier professional league over three seasons from 2016/17-2018/19. The rationale for the study was due to the growing concerns surrounding the risk of neurodegenerative diseases associated with football heading.[1] Before examining relationships between heading and potential risks of neurodegenerative diseases, descriptive studies are needed to assess the incidence and mechanisms of heading in football more closely. Longitudinal studies aiming to understand the potential link between football heading and neurodegenerative diseases should account for head-impact exposure (header and concussion incidence).[10,18,19] Our findings suggest that league, playing position and level of play influence the incidence of heading which should be considered in these longitudinal studies.

Our findings agree with Dellal et al.[13] who found that more heading duels occur in the Premier League than La Liga, on the basis that more heading duels would suggest more headers overall. The headers per match during the Premier League (111.2 headers per match) is similar to the number found by Sandmo et al.[10] for male Norwegian premier leagues matches (112.7 headers per match). The lower tier English Championship had the highest number of headers per match overall. This may partly be due to long balls being executed more frequently in lower level football whereas more passing style play (on the ground) is executed in higher level football in an attempt to retain possession.[20]

Lynall et al.[12] found, using wearable skin-patch sensors, that midfielders, followed by defenders and forwards had the highest number of head impacts per match in female collegiate football. However, the study accounted for all head impacts sustained and wearable skin-patch sensors are known for having high false positive[21] and inaccurate football heading readings.[22] The findings from Lynall et al.[12] differ from the current study though, a direct comparison is not possible due to the abovementioned methodological differences. A previous study in American football identified the benefit of combining wearable head sensor approaches (instrumented mouthguards) with video review as it allows impacts to be video verified and qualitatively described.[23]

The greatest distance travelled by the football was during goal kicks, which accounted for up to 11.5% of headers for forwards. These types of preceding match events are likely to cause the most severe header impacts due to the higher velocity the football travels at,[6] reaching speeds up to 85 km/h (23.6 m/s).[24] Goal kick rule changes could provide an opportunity to decrease the maximum football velocities at which players head the ball at. For example, replacing goal-kicks with throws/roll-outs or head-height rules at certain underage levels as part of a phased introduction to heading. A new goal-kick law trial where the ball is in play once kicked and can be played before leaving the penalty area was introduced by the Football Association in 2019/20 season [25]. This increases the options available to the goalkeeper encouraging shorter passes along the ground, instead of longer, higher speed kick-outs. Studies reconstructing football headers in a laboratory environment can use the reported incidence data as well as the findings for the distance travelled by the football from the preceding match event to design their studies such that it they are more replicable of real-world match heading exposure.

There were several limitations to this study. We provided header information based on the header types and preceding match events along with distance travelled by the football. This allows us to infer the magnitudes of the header impact as larger distances usually require higher initial release velocities. However, we were unable to obtain any severity/speed measures of individual impacts. How these header type and preceding match event classifications translate into actual head accelerations is unknown. Additionally, the distance travelled by the football was calculated using the average size of a Premiership pitch, and thus is only an approximation. Every match over three seasons for 6 leagues

was included except one match from Serie A and the Championship due to an issue with the data feed. Our study focused only on matches as training data were unavailable. To gain a greater understanding of heading exposure for professional footballers, analysis should include training sessions, cup competitions and international fixtures if applicable. Further match analysis of headers in lower level competitions should be conducted. The authors did not have access to data for further lower tier competitions (e.g. English League 1) for the current study.

5. Perspective

The current study presents a detailed assessment of the incidence and mechanism of heading during match play in a large-scale Europe-wide sample of professional football players. Out of the "Big 5" European football leagues, the most headers per match occurred during the Premier League. However, the lower tier English Championship had the highest number of headers per match overall, 25% higher than that of its higher tier counterpart, the Premier League. In all leagues, defenders had the greatest number of match headers per player. The preceding match event for most defender and forward headers was a long ball, whilst for midfielders it was a long ball or headed pass depending on the league. The greatest median distance travelled by the football was during a goal kick, followed by a long ball. The heading incidence and mechanism findings can guide player protection strategies aiming to reduce the incidence and/or severity of a given header impact (e.g. goal kick rule changes). Longitudinal studies aiming to understand the potential link between football heading and neurodegenerative diseases should account for league, playing position and include players from lower level competitions.

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