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Characteristics of potential head injury situations at the FIFA World Cup Qatar 2022™

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ABSTRACT

This exploratory video analysis study aimed to review characteristics of potential head injury situations during a men's professional international football tournament. For 64 matches of the FIFA World Cup Qatar 2022™ FIFA analysts used match footage to record all potential head injury situations. A potential head injury situation was defined as a player staying down for more than 5 s and/or requesting medical attention, and where the body impact location included the player's head. Characteristics were further recorded for match, player (i.e. player action including aerial duels), medical assessment, and outcome (e.g. substitution). Descriptive statistics are reported as well as Pearson's Chi-squared test (or Fisher's exact test) to explore potential head injury situations more likely to result in medical attention. In total, 149 potential head injury situations occurred in 56 matches (mean 2.33/match, range 0–6) involving 117 players. Eight matches resulted in no incidents. Aerial duels were the most frequent match characteristic leading to a potential head injury situation. Injury stoppage with on-pitch medical assessment occurred in 35 of the 149 potential head injury situations (23%), with pitch-side assessment also occurring in 15 situations (10%), resulting in four concussion substitutions. Players were more likely to require medical attention for potential head injuries sustained when the ball was loose ($\chi^2 = 6.88$; $p = 0.038$) when the injured player was jumping (FET $p = 0.044$) and for head-to-head contact (FET $p = <0.001$). Further exploration of aerial duels during match play which do and do not lead to potential and actual head injuries is recommended.

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Soccer; football; concussion; aerial duel

Background

Head injuries account for around 2% of all time-loss injuries in men's professional football (Nilsson et al. 2013), with the most common injuries being contusions, skin lacerations, and concussions (Nilsson et al. 2013; Krutsch et al. 2021), often caused by player-to-player contact when competing for an aerial ball (Beaudouin et al. 2021). The mean return to play time following a concussion ranged from 11 days (English Premier League) to 39 days (Major League Soccer, US) over a ten-year period from 2008 to 2017 (Ramkumar et al. 2019). Following a head injury, performance can also be affected; out-field players in the English Premier League who returned to play following a time-loss concussion injury demonstrated fewer assists, started in fewer games, had fewer shots on goal, and took fewer total shots per year than those without a concussion (Ramkumar et al. 2019). A history of concussion is also a risk factor for a new concussion (Vedung et al. 2020), with the risk increasing by as much as 50% in professional male football players (Nordström et al. 2014), placing importance on the primary and secondary prevention of head injuries. Given the prevalence and potential severity of head injuries in football, further interventions should be explored. Before this can happen, a more detailed and standardised analysis of situations in football which are more likely to lead to a potential head injury is needed. Potential head injury situations (broadened from the earlier published use of potential concussive events) (Abraham et al. 2019) is a term which can be used to capture situations where a player is observed, through video analysis, to experience a direct or indirect blow to the head and is unable to immediately resume play. Early identification and recognition of potential head injury situations is important to ensure that players receive timely assessment to determine whether a diagnosable head injury (such as concussion) has occurred. Understanding and highlighting high-risk head injury situations can help inform the training of match doctors and other medical staff, but also provide information to match officials and coaches, for the benefit of all players. The observation of a potentially injurious head impact (such as those observed in real-time by concussion or injury spotters) (Serner et al. 2023) should trigger a medical follow-up, even if this occurs after the match, given that players have been shown to under-report their concussion symptoms (Meier et al. 2015) and that undiagnosed concussions and delayed management can lead to worse player outcomes including higher symptom severity scores (Lynall et al. 2022).

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Further details on potential head injury situations may also be able to inform injury prevention strategies.

The aim of this exploratory video analysis study was to describe the characteristics of potential head injury situations during the FIFA World Cup Qatar 2022™.

Methods

Data for this study were collected during the FIFA World Cup™ November 20 to 18 December 2022. This tournament consisted of 64 matches, 48 played during the group stage and 16 matches played during the knockout stage. This study is a detailed sub-study of a study reporting on all potential injuries during the FIFA World Cup 2022 reported separately (Clinicaltrials.gov: NCT05629182) (Aiello et al. 2024).

Ethics

Ethics exemption was granted by the Swiss Association of Research Ethics Committees, Kanton Zurich (BASEC-Nr. Req-2022 -01,389).

FIFA Football Language

Data are reported using the 'FIFA Football Language' (including medical coding) which is an open-source, standardised framework for the future analysis of football (FIFA 2023a), based on the Football Injury Inciting Circumstances Classification System (Aiello et al. 2023) and used to report potential injury situations (Aiello et al. 2024). While match analysis that combines football specific and medical information to achieve a better understanding of injury mechanisms and events leading up to higher-risk situations is not new (Andersen et al. 2003), the FIFA Football Language provides operational definitions to clearly define each player and match action. A medical coding was added to the football language to detect situations when the players could be injured (with multiple video examples available online to clearly demonstrate how each definition should be applied) (FIFA 2023b).

Coding

Five FIFA analysts used match footage to analyse and record all potential head injury situations using the medical extension of the FIFA Football Language. This was done remotely using four camera feeds (Tactical, Programme, High Behind, CAM1; resolution: 1280 × 720, format: H.264, data rate: 3.69 Mbit/s). All the analysts held a MSc degree in Performance Analysis, had worked as FIFA Football Analysts for 1 year or more and had completed comprehensive training.

The term 'potential head injury' was used to capture situations where a player remained on the ground for 5 s or longer, and/or indicated to the referee, another player, or a member of staff that they needed medical assessment. The five-second threshold was used to align with FIFA Medical's Concussion Protocol (FIFA 2022). In all potential injuries, the involved body part was scored and for this study, we included all potential injuries determined to be related to the head (including face) by the analyst.

Match characteristics including match number, teams involved, stage of tournament (group or knockout), and time of potential head injury situation (recorded in minutes/seconds using the match clock) were recorded. Additional characteristics are presented in Table 1.

Time characteristics

As well as coding the time the potential head injury situation occurred, the analysts recorded the time taken (in seconds) 1) from when the potential head injury situation occurred to the outcome for the player to demonstrate injury signs, 3) for the referee to signal that medical attention was required, 4) from when medical attention was deemed necessary and the player receiving medical attention, and 5) the time taken to provide medical assessment.

Additional characteristics related to player action

Separately, 25 other FIFA analysts recorded each player action according to the FIFA football language (Table 2). Subsequently, this was combined with the medical coding, meaning that player actions for each potential head injury situation were available and could be compared with the total number of the same player action not resulting in a potential head injury situation.

Referee characteristics (such as yellow/red cards awarded) were also compared to the referee coding of the FIFA football language.

Data analysis

Inter-rater reliability

Inter-rater reliability of analyst coding was undertaken using the *kappaSize* package version 1.2 in RStudio (Version 4.3.0) and was completed in two stages (RStudio 2020). First, five different raters were asked to code a sample of 129 video clips in which 65 clips involved a potential injury incidence and 64 clips did not. Second, 205 clips of injury incidences were then coded by four different raters using the nominal variables of the medical coding framework used in this study. The sample size of video clips required for both these analyses was determined based on a 95% confidence interval (CI) range of 0.6–0.8 which relates to a point estimate of k of 0.7 and a precision of ± 0.1 (Zapf et al. 2016). Reliability was assessed using Fleiss' K using the irr package with bootstrapping applied to simulate 1000 samples and calculation of 95% CI. Results were interpreted as <0.01 (poor), 0.02–0.20 (slight), 0.21–0.40 (fair), 0.41–0.60 (moderate), 0.61–0.80 (substantial), 0.81–1.00 (almost perfect) (Landis and Koch 1977).

The results for inter-rater reliability for the first stage, spotting of potential injury incidences, demonstrated a 95% CI of 0.74–0.84 (substantial to almost perfect agreement). Inter-rater reliability in the second stage of the analysis, which included the medical coding used in this study, demonstrated a 95% CI ranging from 0.34 to 0.48 (fair to moderate agreement) for other player body part to 0.96–1.00 (almost perfect agreement) for injury outcome. The median 95% CI of medical coding was >0.55 (moderate agreement).

Data analysis was completed using STATA version 18 (College Station, Texas, USA). Descriptive statistics are reported for the total number of potential head injury situations using

Table 1. Categories and definitions of player and outcome characteristics recorded for all potential head injury situations.

Characteristics		Categories and definitions
Player	Playing position	Goalkeeper: Player plays in goal Defender: Includes central defenders and full backs Midfielder: Includes defensive, attacking, central and other midfielders Forwards: Includes centre-forwards and wingers
	Possession	In possession: When a player is in controlled possession of the ball. Out of possession: When an opposition player has controlled possession of the ball. Loose ball: When no players are in possession of the ball.
	Contact *(yes/no)*	*If yes, type of contact recorded*: Direct: Direct contact to the head. Indirect: Player is contacted elsewhere on the body (e.g., pushed, pulled). Non-contact: Potential head injury without having any contact with objects or other players.
	Nature of contact *(for direct and indirect contact situations only)*	Opposing Player: Player makes contact with an opposing player (direct/indirect) Teammate: Player makes contact with a teammate (direct/indirect) Pitch Object: Player makes contact with a static pitch object (goal post or corner flag). Ball Contact: Player contact with the ball Other: As specified
	Body part of contacting player *(for direct and indirect contact situations only)*	Head: The contacting player makes head-to-head contact Upper body: The contacting player makes upper body to head contact (includes shoulder, elbow, wrist and hand) Lower body: The contacting player makes lower body to head contact (includes thigh, knee and lower leg) Foot/ankle: The contacting player makes foot/ankle to head contact.
	Movement of the impacted and contacting player *(for direct and indirect contact situations only)*	Static: Player was not moving at the time of the incident. Sliding: Player was intentionally sliding at the time of the incident. Falling: Player loses balance/stability and ends up in a non-upright position on the ground. Walking: Player engaged in locomotion with at least one foot remaining in contact with the ground. Jumping: Player was jumping at the time of the incident. This includes attempting to jump, in the air following a jump, or landing from a jump. Running: Player engaged with continuous and repetitive steps including a flight phase in which both feet are above the ground. This includes accelerating, decelerating, and running at a stead speed.
Outcome	Match response	No signs: Other players do not appear to acknowledge a player is potentially injured. Play on: Players from own or opposition team acknowledge player is potentially injured but continue to play. Referee intervention: Play is stopped due to the referee blowing their whistle
	Referee intervention	Injury stoppage: The referee acknowledges a player may be injured and stops play Foul for: The referee stops the match and calls a freekick. The foul was committed by the other player on the potentially injured player. Foul against: The referee stops the match and calls a freekick. The foul was committed by the potentially injured player
	Injury stoppage	Medic required: The medical staff are required to perform an injury assessment on the injured player (this includes on-pitch and off-pitch). Medic not required: The medical staff are not required to perform an injury assessment on the injured player.
	Outcome of medical assessment	Return to play: Player goes for medical assessment and re-enters the field of play after being signalled by the referee Taken off-walking: Player cannot continue and leaves the field of play (a substitution may occur if the team has sufficient numbers to do so) Taken off- stretcher: The player cannot continue and leaves the field of play by stretcher (a substitution may occur if the team has sufficient numbers to do so) Goalkeeper: The injured player is the goalkeeper meaning they do not need to leave the field of play following medical assessment. Substitution: Following the potential head injury situation, the player is substituted by their team.

counts, means (standard deviation), and percentages for each of the different variables for match, time, referee, and other characteristics. Incidence rates of potential head injury situations are presented as match exposure time using earlier published formulas (match exposure per country/team was calculated as number of matches played × number of players × duration of the match; with incidence rate per 1000 match hours = (number of potential head injury situations/match exposure time) × 1000) (Beaudouin et al. 2020; Peek et al. 2021, 2021). We conducted a post hoc analysis to examine characteristics that were more likely to result in a medical assessment. Independence among these characteristics was assessed using Pearson's chi-squared test (reported in the results as χ^2) or Fisher's exact test (reported as FET) for categorical data. Fisher's exact test was employed in cases where variables had fewer than five observations. Significance level was set at 0.05. Cramer's V, an effect size measurement for the Chi-squared test, is also reported with values of 0.15–0.24 and >0.25 interpreted as a strong or very strong effect size, respectively (Akoglu 2018). This study is completed with reference to the checklist for statistical assessment of medical papers (CHAMP) (Mansournia et al. 2021).

Results

Match characteristics

There were 149 potential head injury situations recorded across 64 matches (mean 2.3 potential head injury situations per match, range 0–6). Across the entire tournament this equates to an incidence rate of 68.8 potential head injury situations per 1000 match hours.

Table 2. Type of player action and corresponding definition.

Player action	Definition
Attempt at goal	A distribution action performed by a player with the intention of scoring a goal.
Ball progression	A distribution action performed by a player with the intention of breaching the opposition team shape by intentionally bypassing one or more opposition players whilst carrying the ball into space or directly beyond an opponent.
Pass	A distribution action performed by a player with the intention of keeping possession of the ball. A player can manoeuvre the ball on the ground or aerially between themselves and a team-mate.
Offering to receive	A clear and deliberate action performed in an attempt to receive the ball, which has an impact on the current in-possession phase. This action can be via a clear and obvious signal or a movement (including a change in body shape).
Clearance	A player attempts to clear the ball up field or out of play, usually to relieve the pressure or danger faced by themselves or their team.
Block	A player attempts to stop the opposition's in-possession action reaching its intended target without the aim of retaining possession of the ball for themselves (includes blocked pass, blocked cross, blocked clearance, blocked attempt at goal).
Tackle	An attempt by a player to dispossess their opponent.
Pressing	A player has closed space between themselves and an opposition player on the ball with the intention of reducing time and space for the opponent.
Pushing on	A player attempts to close the space between themselves and an opposition player when the opposition player does not have the ball.
Aerial duel	Two or more players compete for a ball that is above shoulder height; at least one player is off the ground and is being physically challenged by an opposition player.
Other duel	Includes *physical duel* where two or more players compete physically to either win or retain possession of the ball for their team and all the players involved are on the ground. The duel must have started prior to either player receiving the ball; and *duel* where two or more players from opposing teams compete to win possession of a loose ball on the ground.

From 831 listed players, 680 players played in at least one match, with 117 players of these (17%) being involved in a potential head injury situation. This includes 96 players who were involved in one potential head injury situation, 15 players who were involved in two situations, four players involved in three and two players involved in four potential head injury situations. Ten players were involved in two potential head injury situations within the same match.

There were 110 potential head injury situations in the group stage (74%; 2.3/match, 69.4/1000 match hours) and 39 (26%, 2.4/match; 66.9/1000 match hours) in the knockout stage. There were eight matches without a potential head injury situation (seven = group stage and one = knockout stage). From 32 teams, 31 had at least one potential head injury situation recorded across the tournament (mean 4.7 per team, range 0–16) (see supplementary file 1 for data for each country).

Regarding match time, 58 (39%) potential head injury situations occurred in the first half ($n = 18$ required medical assessment) and 87 (58%) occurred in the second half of matches ($n = 15$ requiring medical assessment) across the tournament. Of the five matches in the knockout stage that went to extra time, five (3%) potential head injury situations occurred during extra time with two requiring medical assessment, Figure 1.

Player characteristics

The most frequent potential injury sign was staying down for 5 s ($n = 144$, 97%), whereas signalling for assistance without staying down was registered in five incidents (3%). At the time the potential head injury situation occurred, the ball was loose in 65 (44%) incidents. The impacted player was in possession of the ball in 52 (35%) incidents and in the opponent's possession in 32 (21%) incidents.

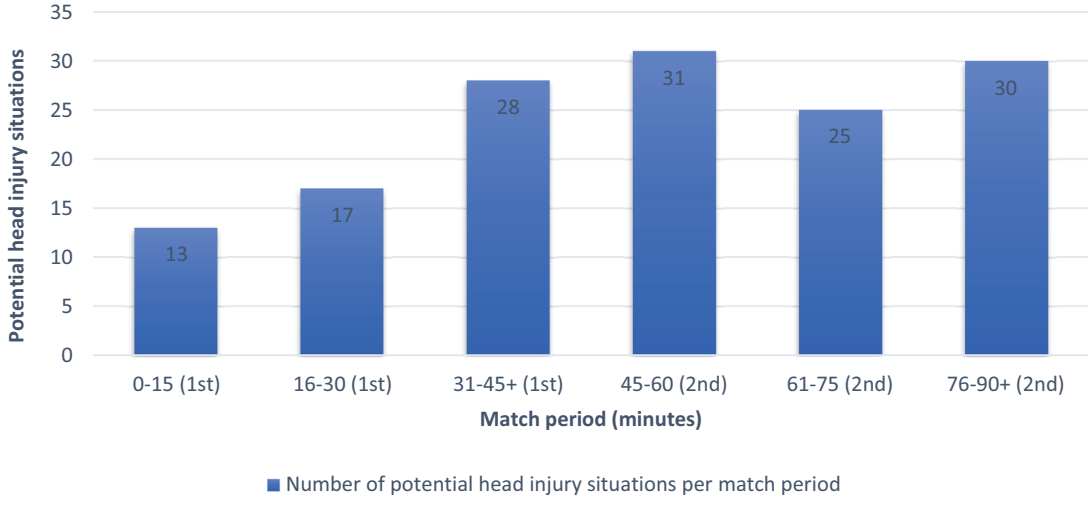

Figure 1. Number of potential head injury situations per match time-period (in minutes) across the tournament. Key: 1st= first half, 2nd= second half. Three potential head injury situations occurred in the first period of added time (45+1 min, 45+3 min, 45+6 min) and 12 potential injuries occurred in the second period of added time (90+1 min (x3), 90+2 min (x3), 90+3 min, 90+4 min (x4), 90+5 min). In addition, five matches went to extra time; in these five matches, three potential head injury situations occurred in extra time-period one, and two potential head injuries occurred in extra time-period two.

Fifty-one (34%) potential head injury situations involved defenders (25 centre-backs and 26 full backs), 52 (35%) involved midfielders (23 central midfielders, 11 defensive midfielders, 10 attacking midfielders and 8 other midfielders), 45 (30%) involved forward players (27 centre forwards and 18 wingers) and 1 (1%) involved a goalkeeper.

The most frequent cause of a potential head injury situation was direct contact ($n = 143$, 96%). Of the 143 contact situations, 124 (87%) involved contact with an opponent player, 10 (7%) involved a teammate and 9 (6%) involved the ball. In player-to-player contact events ($n = 134$), the direct contact from the other player was most frequently with the upper body ($n = 83$, 56%) followed by the head ($n = 31$) (Table 3).

The referee stopped play to enable on-pitch medical assessment for 35 potential head injury situations (23%). Head–to-head contact led to more on-pitch medical assessment than any other opponent body part (n = 15, 43%), Table 3. Players were more likely to require medical attention for potential head injuries sustained when the ball was loose (χ^2 (Krutsch et al. 2021) = 6.88; p = 0.038, Cramer's V = 0.215) than any other ball possession situation, when the injured player was jumping (FET = p = 0.044, Cramer's V = 0.273) compared to any other physical activity, and for head-to-head contact (FET (Meier et al. 2015) = p = <0.001, Cramer's V = 0.535) compared to any other head contact.

When there was player-to-player contact ($n = 135$), the most frequent player activity type of the impacted player was jumping ($n = 61$, 45%) and running ($n = 55$, 41%). When both players were jumping, 49 potential head injury situations (80%) occurred when both players were in the air, five (8%) when the impacted player was taking off and the other player was in the air, two situations (3%) occurred when both players were taking off, and one situation (2%) occurred when the impacted player was landing, and the other player was in the air. If one or more players were running when the potential head injury situation occurred, most happened when the impacted player ($n = 28$) or both players ($n = 22$) were running at a steady speed followed by the impacted player ($n = 12$) or both players ($n = 8$) accelerating. Only two potential head injury situations occurred when the involved player was decelerating and none when both players were decelerating (see supplementary file 2 for data relating to activity type (impacted and other player) and opponent's body part making direct head contact).

Player action

Across the whole tournament, the most common player action leading to a potential head injury situation across all teams was an aerial duel (Table 4). There were 4851 aerial duels in total (mean 75.8 per match; SD 25.5, range 37–170), giving an incidence rate (IR) of 2037/1000 match hours. In eight matches, 100 or more aerial duels were recorded. Six of these were in the group stage: Cameroon v Serbia ($n = 100$); Ecuador v Senegal ($n = 107$); Uruguay v South Korea ($n = 120$); Australia v Denmark ($n = 121$), Mexico v Poland ($n = 129$); Tunisia v Australia ($n = 159$); and two in the knockout stage: Argentina v France ($n = 101$), Japan v Croatia ($n = 170$). Australia was involved in two matches with two of the highest number of aerial duels despite being the only country with no recorded potential head injury situations in any of their matches. In 46 (31%, IR 19.2/1000 match hours) potential head injury situations, players were involved in an aerial duel. When considering the total number of aerial duels across the entire tournament, only 1% of aerial duels led to a potential head injury situation. Of the 46 aerial duels which led to a potential head injury situation, 25

Table 3. Overview of contact type in potential head injury situations stratified by the provision of on-pitch medical attention.

Contact type	All potential head injury situations (n=149)	Potential head injury situations with on-pitch medical attention (n=35)	Potential head injury situations with no on-pitch medical attention (n=114)	Potential head injury situations where the other player was sanctioned by referee (n=19)
Direct Contact with opponent's body part	**134 (89%)**	**29 (83%)**	**105 (92%)**	–
Head	**31 (21%)**	**15 (43%)**	**16 (14%)**	–
Upper body	**83 (56%)**	**9 (26%)**	**74 (65%)**	**Yellow cards (16, 84%)**
Elbow	22 (15%)	3 (9%)	19 (17%)	(7, 37%)
Hand	20 (13%)	2 (6%)	18 (16%)	(1, 5%)
Lower arm	16 (11%)	0 (0%)	16 (14%)	(3, 16%)
Upper arm	13 (9%)	2 (6%)	11 (10%)	(4, 21%)*
Shoulder	6 (4%)	2 (6%)	4 (4%)	(1, 5%)
Upper body-unidentifiable location	6 (4%)	0 (0%)	6 (5%)	–
Trunk	**11 (7%)**	**2 (6%)**	**9 (8%)**	**Red card (1, 5%)** **Yellow card (1, 5%)**
Lower body	**9 (6%)**	**3 (3%)**	**6 (5%)**	**Yellow card (1, 5%)**
Foot	6 (4%)	2 (0%)	4 (5%)	(1, 5%)
Thigh	1 (<1%)	0 (0%)	1 (1%)	–
Knee	1 (<1%)	1 (3%)	0 (0%)	–
Lower leg	1 (<1%)	0 (0%)	1 (1%)	–
Ball	**9 (6%)**	**4 (12%)**	**5 (4%)**	–
Indirect contact	**2 (1%)**	**0 (0%)**	**2 (2%)**	–
No contact	**2 (1%)**	**1 (3%)**	**1 (<1%)**	–
Unidentifiable	**2 (1%)**	**1 (3%)**	**1 (<1%)**	–

The 'bold' figures denote each category with upper and lower body further described by additional body locations within each category. *includes the one yellow card that was given to the injured player

Table 4. Recorded player action for each potential head injury situation compared with the total number of the same player action not resulting in a potential head injury situation.

Player action	Total player actions in all matches	Mean number of actions per match (SD; range)	Number (%) of each actions leading to potential head injury situation	Mean potential head injury situations caused by this action per match (range)	Potential head injuries for this action requiring medical assessment n (%)*
Aerial duel	4851	75.8 (25.5; 37–170)	46 (1%)	1 (0–4)	25 (54%)
Offering to receive	73126	1142.5 (299.8; 721–2086)	14 (<0.1%)	0.2 (0–2)	2 (14%)
Ball progression	2707	42.3 (10.4; 22–75)	9 (0.3%)	0.1 (0–1)	1 (11%)
Clearance	4089	63.9 (17.3; 31–119)	7 (0.2%)	0.1 (0–1)	1 (14%)
Pressing	37313	583.0 (81.6; 433–790)	6 (<0.1%)	0.1 (0–1)	1 (17%)
Other duel	1627	25.4 (8.1; 12–50)	5 (0.3%)	0.1 (0–2)	0 (0%)
Block	3069	48.0 (9.3; 23–72)	5 (0.2%)	0.1 (0–1)	3 (60%)
Attempt at goal	1476	23.1 (6.9; 10–40)	4 (0.2%)	0.1 (0–1)	1 (25%)
Pass	61480	960.6 (149.3; 660–1373)	4 (<0.1%)	0.1 (0–1)	0 (0%)
Tackle	4240	66.8 (15.5; 38–122)	3 (0.1%)	<0.1 (0–1)	1 (33%)
Pushing on	44384	693.5 (108.9; 490–1003)	2 (<0.1%)	<0.1 (0–1)	0 (0%)

*Percentage is calculated in relation to the number of potential head injuries for that specific player action.

(54%, IR 1 0.4/1000 match hours) required on-pitch medical assessment (Table 4).

Outcome characteristics

The match was stopped in 114 potential head injury situations (78%), with no action taken by the referee in 36 situations (24%). When the referee took action, a foul for the impacted player was given in 60 situations, with a foul against the impacted player in eight situations. Across the entire tournament, there were 3172 fouls called by referees ($n = 1529$ fouls for; $n = 1643$ fouls against; mean 49.6 per match), with 68 (2.1%) being related to potential head injury situations (mean 1.1 per match). In addition, the referee gave out one red card and 18 yellow cards related to potential head injury situations (17 yellow cards were given to the other player, with one yellow card given to the potentially injured player). The incident leading to the red card as well as one incident involving a yellow card given to the other player for elbow-to-head contact required on-pitch medical assessment.

In total, the referee called an injury stoppage to enable on-pitch medical assessment for 35 potential head injury situations (23%), with pitch-side assessment also occurring in 15 situations (10%) resulting in three immediate substitutions, where all three teams used the additional concussion substitution. One additional player was substituted later in the match using a concussion substitution.

Time characteristics

For potential head injury situations where medical attention was required, a mean of 10.3 s (SD 4.9 s, range 3–20 s) elapsed between the referee signalling the medical team to come on the pitch and the commencement of medical assessment. The mean time taken to provide on-pitch medical assessment was 56.1 s (SD 61.9 s, range 4–171 s). For off-pitch assessments, the mean duration of assessment was 24.2 s (SD 32.2, range 1–125 s). Total mean time for medical assessment combined was 63.2 s (SD 62.0 s, range 5–321 s).

Discussion

This exploratory video analysis study reports the characteristics of potential head injury situations during the 2022 FIFA World Cup™. The collection of data related to potential head injury situations and not just diagnosed or verified head injuries is important given the research and clinical concerns surrounding the relationship between head impacts and long-term brain health of football players (Ueda et al. 2023). While the incidence of headers (Roman et al. 2023) and concussion (Nilsson et al. 2013) have been reported in professional football players, data on potential head injuries are limited. Concussion is often seen as a 'silent injury' and relies on a combination of the following to support a diagnosis: 1) direct or indirect head impact event, 2) player reported symptoms, 3) physical or clinical signs of injury. If the head impact event is missed, the player does not report any symptoms and there are no physical signs that a head impact has occurred such as bruising or laceration, then this injury could easily be missed, making data on the number and cause of potential head injury situations a useful addition to the literature. In total 149 potential head injury situations were recorded, 35 requiring on-pitch medical attention, with a mean time of 56.1 secs to provide assessment. Direct

upper-body-to-head or head-to-head contact were the most common mechanisms for a potential head injury situation, with aerial duels being the most common player action to lead to a potential head injury situation. Players were also significantly more likely to require medical attention for potential head injuries sustained when the ball was loose, when the injured player was jumping, and for head-to-head contact.

The mean potential head injury situations per match in 2022 were 2.3 (IR 68.8/1000 match hours), which is higher than the IR for head collision events reported from the 2014 Men's World Cup (32.5/1000 match hours) (Cusimano et al. 2017) and 2018 Men's World Cup (54.5*/1000 match hours -**estimated IR from the reported data*) (Premkumar et al. 2019). Methodological differences in how these data were recorded (and the definitions of each variable) mean that the direct comparison of these data should proceed with caution. It is possible that the difference in how potential head injuries were defined across these three studies explains the variation observed in IR. For instance, the two earlier studies collected head collision event data with an emphasis on observing signs of concussion (Cusimano et al. 2017; Premkumar et al. 2019). In our study, the definition of a potential head injury situation was broadened to include non-head collision events such as body contact leading to an indirect head injury without an emphasis on the observable signs of a concussion. Moving forward, the continued use of a standardised framework will facilitate more direct comparison of data in future tournaments.

When considering the number of potential head injury situations requiring medical assessment, these data are comparable across FIFA World Cup studies. In the 2014 World Cup, 45 head injuries required on-pitch assessment (12 players also required pitch-side care and two incidences resulted in the player being substituted) (Cusimano et al. 2017). In 2018, 35 potential head injuries required on-pitch or pitch-side care, with six players being substituted (Premkumar et al. 2019). Our data demonstrated very similar findings with 35 potential head injuries receiving on-pitch medical assessment, with players also receiving pitch-side care in 15 situations with four players substituted. These data indicate that the number of medically assessed head injuries across the last three World Cup tournaments has remained low in number and largely unchanged. As there has been an increasing focus on concussion in recent years, including in FIFA tournaments, it would be reasonable to expect an increasing number of on-pitch medical assessments. Therefore, the constant numbers may actually indicate a reduction in the number of serious events. Of additional note, the mean time to provide on-pitch medical assessment (56.1 s) has remained consistently below 1 min in the last three FIFA Men's World Cups (Cusimano et al. 2017; Premkumar et al. 2019), despite three-minutes being permitted to complete this assessment. While further exploration of the reasons for the short duration of medical assessment in future football tournaments appears warranted (Serner et al. 2023), it is possible that most incidents were so trivial that medical teams were able to complete their assessments quickly without extensive examination. Although upper body-to-head contact resulted in the most potential head injury situations ($n = 83$), only nine of these (11%) required on-pitch medical assessment compared to 15 out of 31 (48%) head-to-head potential head injury situations. From a medical or injury spotter perspective, further scrutiny of head-to-head contact events is recommended.

In our study, players in the central corridor (centre-backs, central midfielders and centre-forwards) were more likely to be involved in a potential head injury situation, with goalkeepers being involved in the least. Although positional data are often challenging to interpret given that team formations often change depending on a number of factors including which combinations of players are on the pitch at that time and whether the team is in possession of the ball or not, this finding is consistent with earlier studies (Putukian et al. 2019; Nelson et al. 2020; Krutsch et al. 2021). It is interesting to note that despite central defenders generally being responsible for more headers in men's football (Beaudouin et al. 2020; Peek et al. 2021), they were not involved in the most potential head injury situations, the reasons for this require further investigation, particularly whether differences in training or exposure to heading and aerial duels might be a factor.

Not surprisingly, players were more likely to be involved in a potential head injury situation through direct contact with an opposition player, through head-to-head or elbow-to-head contact, particularly when both players were jumping. Jumping was also the most frequent action performed by injured players recorded by video analysis across 12 seasons of the Men's Bundesliga (2000/1 to 2012/13) (Beaudouin et al. 2019b). Earlier studies consistently demonstrate that loose aerial balls are the most common risk factor for head injuries due to player-to-player contact (Andersen et al. 2004; Fuller et al. 2005; Beaudouin et al. 2019a, 2019b; Weber et al. 2022). While aerial duels were involved in 43% of potential head injury situations in our study, given the high number of aerial duels observed across the tournament ($n = 4851$) a very small percentage (1%) led to a potential head injury situation. Nevertheless, educating players appropriate behaviour including awareness and body positioning in aerial duels to reduce head contact would appear justified as a primary injury prevention strategy (Weber et al. 2022).

Elbow-to-head contact is a frequent cause of head injury (Beaudouin et al. 2019b) with an earlier study demonstrating that head injuries in the Bundesliga were reduced by 29% following a 2006 rule change for referees to award players a red card for intentional elbow-to-head contact (Beaudouin et al. 2019a). Ensuring referees are educated and supported to enforce this rule is an important head injury prevention initiative. In our study, the referee considered that foul play was the cause of a potential head injury situation in 60% of instances involving elbow-to-head contact (with seven players also being given a yellow card). This compares to 26% in the earlier study in the Men's Bundesliga (2000–2013) (Beaudouin et al. 2019b) and 30% in the Men's Norwegian and Icelandic professional leagues (1999–2000 seasons) (Andersen et al. 2004). These differences over time suggest that current referees have an increased awareness of the seriousness of head injuries

and a willingness to penalise players for foul play in these injury situations, including sanctioning players with yellow ($n = 18$) and red cards ($n = 1$) as observed in our study.

Translation of findings into practice and recommendations for future research

While the findings of this study are limited to one tournament in professional men's football, there are indicators of match situations and player actions that might be considered higher risk of a potential head injury that could be used to inform injury prevention initiatives and direct future research. One recommendation is that coaches and medical staff work together to co-design coaching frameworks that support players in developing technical proficiency in heading, which should include the ability to safely execute this skill in high-pressure contact situations to protect players from potential head injuries. In our study, aerial duels led to more potential head injury situations than any other player action; therefore, it would appear logical that when coaching the skill of heading, technique acquisition should include all skill-based attributes, such as spatial awareness, point of head contact, ball tracking, timing of runs, jumps, and other player movements in both contested and uncontested situations. Further, future research could explore the differences between aerial duels with different outcomes: no injury risk, potential head injury, potential head injury with on-pitch medical assessment, and diagnosed head injury (when sufficient incidents are detected through separate injury surveillance projects). Future research which explores the interactions of all these characteristics using a much larger sample size of potential head injury situations in both men and women and across a range of skill levels and ages is recommended to further extrapolate our initial findings and better inform injury prevention initiatives.

Limitations

As the data only include male professional players competing within a 64-match international tournament, generalisability is limited. It has been recognised that female players are at higher risk of sustaining a head injury across many contact sports including football (Prien et al. 2018), therefore, repeating this recording methodology at the 2023 FIFA Women's World Cup™ would be an important addition to the literature. The detailed analysis in this study was made possible by the number of experienced analysts involved in data coding using high-definition match footage from multiple camera angles which is not possible for most tournaments or leagues in lower levels of football, including those involving younger players. Despite the high level of expertise, there were a small number of missing data where variables could not be coded and while the inter-rater reliability of medical coding was moderate or above, it is acknowledged that some variables were more reliable to code than others such as injury outcome. Given that our analysts had access to high-definition match video footage, it is likely that some of these variables would be less accurate to code with poor quality footage. Finally, without access to medical records, actual head injuries for specific incidents could not be confirmed. Therefore, the best indicator of the seriousness of potential head injury situations in the 2022 FIFA World Cup is provided by the number of situations where on-pitch medical assessment occurred, as well as the number of concussion substitutions used.

Conclusion

In the 2022 FIFA World Cup, players were more likely to be involved in a potential head injury situation through direct player-to-player contact when the ball was loose, usually when two players were jumping during an aerial duel (whereby increasing the risk of upper-body to head contact). Although the overall number of aerial duels across the tournament that lead to a potential head injury situation was very low, this injury mechanism highlights the need to further explore the characteristics that differentiate between an injurious and non-injurious aerial duel.

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Contributorship

AS: Conceptualization, Methodology, Project Administration, Writing – Review & Editing
KP: Data curation, Formal Analysis, Visualization, Writing – Original draft.
FA: Methodology, Data curation, Writing – Review & Editing
LA, TG, HR: Methodology, Investigation, Resources, Writing – Review & Editing
AM: Methodology, Writing – Review & Editing
TEA, JG, SD: Writing – Review & Editing

Data sharing

Data are available upon reasonable request from Andreas.Serner@FIFA.org.

Ethical approval

Ethics exemption was granted by the Swiss Association of Research Ethics Committees, Kanton Zurich (BASEC-Nr. Req-2022 -01,389), and the overall study was registered on clinicaltrial.gov (NCT05629182).

Patient and public involvement

No members of the public were involved in the development of this project due to its observational study design and the inclusion of all potential head injury situations.

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References

Abraham KJ, Casey J, Subotic A, Tarzi C, Zhu A, Cusimano MD. 2019. Medical assessment of potential concussion in elite football: video analysis of the 2016 UEFA European championship. J BMJ Open. 9(5):e024607. doi: 10.1136/bmjopen-2018-024607.

Aiello F, Avery L, Gardner T, Rutherford H, McCall A, Impellizzeri FM, Peek K, Della Villa F, Massey A, Serner A, et al. 2024. Broadening our understanding of injury mechanisms to include at-risk situations: an overview of potential injuries at the FIFA men's world cup Qatar 2022TM. Sci Med Football. 1–10. doi: 10.1080/24733938.2024.2372304.

Aiello F, McCall A, Brown SJ, Serner A, Fortington LV, Huurman SAE, Lewin C, Nagao M, O'Brien J, Panossian A, et al. 2023. Development of a standardised system to classify injury-inciting circumstances in football: the Football Injury Inciting Circumstances Classification System (FIICCS). Sports Med. 53(9):1805–1818. doi: 10.1007/s40279-023-01857-6.

Akoglu H. 2018. User's guide to correlation coefficients. Turk J Emerg Med. 18(3):91–93. doi: 10.1016/j.tjem.2018.08.001.

Andersen TE, Arnason A, Engebretsen L, Bahr R. 2004. Mechanisms of head injuries in elite football. Br J Sports Med. 38(6):690–696. doi: 10.1136/bjsm.2003.009357.

Andersen TE, Larsen Ø, Tenga A, Engebretsen L, Bahr R. 2003. Football incident analysis: a new video based method to describe injury mechanisms in professional football. Br J Sports Med. 37(3):226–232. doi: 10.1136/bjsm.37.3.226.

Beaudouin F, Aus der Fünten K, Tröß T, Reinsberger C, Meyer T. 2019a. Head injuries in professional male football (soccer) over 13 years: 29% lower incidence rates after a rule change (red card). Br J Sports Med. 53 (15):948–952. doi: 10.1136/bjsports-2016-097217.

Beaudouin F, Aus der Fünten K, Tröß T, Reinsberger C, Meyer T. 2019b. Time trends of head injuries over multiple seasons in professional male football (soccer). Sports Med Int Open. 3(1):E6–E11. doi: 10.1055/a-0808-2551.

Beaudouin F, Demmerle D, Fuhr C, Tröß T, Meyer T. 2021. Head impact situations in professional football (soccer). Sports Med Int Open. 5(2): E37–E44. doi: 10.1055/a-1338-1402.

Beaudouin F, Gioftsidou A, Larsen MN, Lemmink K, Drust B, Modena R. 2020. The UEFA heading study: heading incidence in children's and youth'-football (soccer) in eight European countries. Scand Med Sci Sports. 30 (8):1506–1517. doi: 10.1111/sms.13694.

Cusimano MD, Casey J, Jing R, Mishra A, Solarski M, Techar K, Zhang S. 2017. Assessment of head collision events during the 2014 FIFA world cup tournament. Jama. 317(24):2548–2549. doi: 10.1001/jama.2017.6204.

FIFA. 2022. FIFA medical concussion protocol. Zurich, Switzerland: FIFA.

FIFA. 2023a. FIFA football language. https://www.fifatrainingcentre.com/en/resources-tools/football-language/index.php.

FIFA. 2023b. Study the FIFA football language Zurich, Switzerland. https://www.fifatrainingcentre.com/en/resources-tools/football-language/.

Fuller C, Junge A, Dvorak J. 2005. A six year prospective study of the incidence and causes of head and neck injuries in international football. Br J Sports Med. 39(suppl 1):i3–i9. doi: 10.1136/bjsm.2005.018937.

Krutsch V, Krutsch W, Härtl J, Bloch H, Alt V, Klein C, Reinsberger C, Seiffert R, Huber L, Weber J, et al. 2021. Head injuries in professional football (soccer): results of video analysis verified by an accident insurance registry. PLOS ONE. 16(8):e0255695. doi: 10.1371/journal.pone.0255695 .

Landis JR, Koch GG. 1977. The measurement of observer agreement for categorical data. J Biom. 33(1):159–174. doi: 10.2307/2529310.

Lynall RC, D'Lauro C, Kerr ZY, Knight K, Kroshus E, Leeds DD. 2022. Optimizing concussion care seeking: the influence of previous concussion diagnosis status on baseline assessment outcomes. Am J Sports Med. 50(12):3406–3416. doi: 10.1177/03635465221118089.

Mansournia MA, Collins GS, Nielsen RO, Nazemipour M, Jewell NP, Altman DG, Campbell MJ. 2021. A checklist for statistical assessment of medical papers (the CHAMP statement): explanation and elaboration. Br J Sports Med. 55(18):1009.2–1017. doi: 10.1136/bjsports-2020-103652.

Meier TB, Brummel BJ, Singh R, Nerio CJ, Polanski DW, Bellgowan PS. 2015. The underreporting of self-reported symptoms following sports-related concussion. J Sci Med Sport. 18(5):507–511. doi: 10.1016/j.jsams.2014.07.008.

Nelson KM, Daidone EH, Breedlove KM, Bradney DA, Bowman TG. 2020. Head impact characteristics based on player position in collegiate soccer athletes. Int J Athletic Ther Train. 26(2):111–115. doi: 10.1123/ijatt.2019-0095.

Nilsson M, Hägglund M, Ekstrand J, Waldén M. 2013. Head and neck injuries in professional soccer. Clin J Sport Med. 23(4):255–260. doi: 10.1097/JSM.0b013e31827ee6f8.

Nordström A, Nordström P, Ekstrand J. 2014. Sports-related concussion increases the risk of subsequent injury by about 50% in elite male football players. Br J Sports Med. 48(19):1447–1450. doi: 10.1136/bjsports-2013-093406.

Peek K, Meyer T, Beaudouin F, McKay M. 2021. Heading incidence in boys' football over three seasons. Sciamp Med Football. 5(3):175–180. doi: 10.1080/24733938.2020.1849783.

Peek K, Vella T, Meyer T, Beaudouin F, McKay M. 2021. The incidence and characteristics of purposeful heading in male and female youth football (soccer) within Australia. J Sciamp Med Sport. 24(6):603–608. doi: 10.1016/j.jsams.2020.12.010.

Premkumar A, Farley KX, Anastasio AT, Lee S-W, Mirza F, Gottschalk MB, Xerogeanes J. 2019. Video assessment of the frequency and evaluations of head collision events during the 2018 world cup tournament. JAMA Neurol. 76(2):232–234. doi: 10.1001/jamaneurol.2018.3462.

Prien A, Grafe A, Rössler R, Junge A, Verhagen E. 2018. Epidemiology of head injuries focusing on concussions in team contact sports: a systematic review. Sports Med. 48(4):953–969. doi: 10.1007/s40279-017-0854-4.

Putukian M, Echemendia RJ, Chiampas G, Dvorak J, Mandelbaum B, Lemak LJ, Kirkendall D. 2019. Head injury in soccer: from science to the Field; summary of the head injury summit held in April 2017 in New York City, New York. Br J Sports Med. 53(21):1332–1332. doi: 10.1136/bjsports-2018-100232.

Ramkumar PN, Navarro SM, Haeberle HS, Luu BC, Jang A, Frangiamore SJ, Farrow LD, Schickendantz MS, Williams RJ. 2019. Concussion in American versus European professional soccer: a decade-long comparative analysis of incidence, return to play, performance, and longevity. Am J Sports Med. 47(10):2287–2293. doi: 10.1177/0363546519859542.

Roman I, McKay M, Peek K. 2023. Head impact events in youth football in India and Australia, compared to FIFA Men's world cup matches. JSAMS Plus. 2:100029. doi: 10.1016/j.jsampl.2023.100029.

RStudio. 2020. Integrated development for R [program]: RStudio, PBC.

Serner A, Araújo J, Beasley I, Boyce SH, Byrne A, Börjesson M, Geertsema L, Grimm K, Massey A. 2023. Video review of the frequency and assessment of head impacts during the FIFA arab cup 2021TM. Sci Med Football. 7 (4):331–336. doi: 10.1080/24733938.2022.2120629.

Ueda P, Pasternak B, Lim C-E, Neovius M, Kader M, Forssblad M, Ludvigsson JF, Svanström H. 2023. Neurodegenerative disease among male elite football (soccer) players in Sweden: a cohort study. Lancet Public Health. 8(4):e256–e265. doi: 10.1016/S2468-2667(23)00027-0.

Vedung F, Hänni S, Tegner Y, Johansson J, Marklund N. 2020. Concussion incidence and recovery in Swedish elite soccer—prolonged recovery in female players. Scand Med Sci Sports. 30(5):947–957. doi: 10.1111/sms.13644.

Weber J, Reinsberger C, Krutsch V, Seiffert R, Huber L, Alt V, Krutsch W. 2022. Heading and risk of injury situations for the head in professional German football: a video analysis of over 150,000 headers in 110,000 match minutes. Sci Med Football. 7(4):1–8. doi: 10.1080/24733938.2022.2114602.

Zapf A, Castell S, Morawietz L, Karch A. 2016. Measuring inter-rater reliability for nominal data–which coefficients and confidence intervals are appropriate? BMC Med Res Methodol. 16(1):1–10. doi: 10.1186/s12874-016-0200-9.