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Differences in the technical performance of heading between men and women football players during FIFA World Cup 2022 and FIFA Women's World Cup 2023 matches

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ABSTRACT

Objectives To compare the incidence of headers, attempted headers, and other head impacts, and the difference in heading descriptors, including technical performance, between men and women in a purposive sample of FIFA World Cup 2022 (FWC22) and FIFA Women's World Cup (FWWC23) matches.

Methods Video analysis of all observed headers, attempted headers and other head impacts during eight FWC matches (FWC22 (n=4); FWWC23 (n=4)) where the same national teams competed. Heading descriptors (including ball delivery method, purpose of the header and involvement of other players) and technical performance of each header (including controlled or uncontrolled header, use of upper body, point of head contact) were analysed using negative binomial regression analyses with men as the reference group (reported as incidence rate ratios (IRR)). Timing of eye closure was analysed using a t-test; α-error, p=<0.05.

Results From 973 head impacts, 845 (87%) were headers (FWC22 mean 5.0 headers/player/match, FWWC23 mean 4.6 headers/player/match), 93 (10%) were attempted headers and 35 (4%) were unintentional head impacts. When compared with men, women were less likely to perform controlled headers (73% vs 83%, IRR 1.20, p=0.01), use their foreheads (IRR 2.36, p=<0.001) and their upper body during the header (80% vs 88%, IRR 1.29, p=0.005). Women also closed their eyes earlier before the header (1.91 vs 1.56 frames, d=0.41, p=0.002).

Conclusion There were significant differences in heading technique between women and men, which could be important to address in training to improve heading performance and potentially reduce short-term and long-term burden of heading.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ While heading performance has been explored in men, there is a paucity of data in women. While the most common mechanism of head injury (including concussion) is from player-to-player contact when two or more players compete for a header during an aerial duel, women football players are more likely to be injured by the ball itself when compared with men. The reasons for these differences are unknown.

WHAT THIS STUDY ADDS

⇒ This study provides new information regarding differences in the technical performance of heading between professional men and women. In a purposive sample of FIFA World Cup matches, we found that women performed fewer controlled headers than men, were less likely to head the ball using their foreheads and were less likely to use their upper body when compared with a similar sample of men. Additionally, women were more likely to head the ball from corners and goal kicks, whereas men were more likely to head the ball during free play and long balls. Women were also more likely to head the ball to intercept play, with men more likely using headers to pass the ball. Finally, we found that women closed their eyes earlier before the header when compared with men.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings from this study could be used to inform sex-specific coaching frameworks and heading guidelines to support players to develop technical proficiency in heading skill development, which may also potentially reduce the head injury risk and burden associated with heading.

INTRODUCTION

Heading is a football-specific skill that can determine match results in Association Football, with headers being the second most efficient goal-scoring technique, following kicks during free play.[1] In the 2022 UEFA Women's European Championship, 28% of all goals were scored from a header, and 19% of all goals in the 2020 UEFA Men's European Championship.[2] It has been estimated that the mean number of headers per player per match is 2.7 and 5.0 headers in boys' and men's football compared with 2.3 and 4.8 headers in girls' and women's football.[3 4]

There is limited heading incidence data in professional women's football[5] and while studies exploring some aspects of technical proficiency of heading during match play exist in men,[6–8] there is paucity of such data in women.

While heading guidelines exist in some countries to limit or prohibit heading in certain age-groups, none has any sex distinctions or consider heading technique.[9 10] An emerging area of scientific enquiry is whether there are technical differences in heading performance between men and women and whether these should be considered when developing heading guidelines and/or coaching frameworks.[11] For example, women reportedly close their eyes more often than men when performing a header.[12 13] While a very small number of studies exist that have explored heading technique within a laboratory study,[14 15] there is a paucity of data in professional men's and women's football during match play. Heading is a complex skill, with the actual head-to-ball contact being only one component. To execute an effective header, players need to be able to track the trajectory of the ball and time their movement (including the timing of their run and/or jump as well as the movement of the head, trunk and hips) in readiness for head-to-ball contact.[11 15] Despite the complexity and importance of heading as well as the frequency in which this skill is performed, very few heading coaching frameworks currently exist on how to coach heading with 50% of players reporting that they have never been taught how to head a ball (with this figure being lower in women and girls).[16] Teaching players how to execute an effective header potentially has important implications for head injury prevention, given that the most common mechanism of head injury (including concussion) is from player-to-player contact when two or more players compete for a header during an aerial duel, where the use of protective body positioning could assist in decreasing injury risk.[11] Furthermore, women and girls are more likely to be injured by the ball itself,[17] which may be influenced by a lack of anticipation of ball contact due to the eyes being closed.[11] To explore these factors and inform future heading coaching frameworks and guidelines, more information is needed on heading descriptors, including technical performance of headers in both men and women.

Objectives

The objectives of this descriptive video analysis study were to compare the incidence of headers, attempted headers and other head impacts and the difference in heading descriptors, including technical performance, between men and women in a purposive sample of FIFA World Cup 2022 (FWC22) and FIFA Women's World Cup 2023 (FWWC23) matches.

Hypotheses

Hypothesis 1: professional women football players will perform fewer headers than professional men.

Hypothesis 2: there will be differences in heading technique between men and women, including that women will close their eyes earlier than men when heading a ball.

METHODS

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 observed players and all types of head impacts.

Equity, diversity and inclusion statement

Data were collected during the FWC22 and FWWC23 and include equal numbers of men and women. The authorship team includes two women (50%) including the lead author as well as a mix of clinical backgrounds (physiotherapy and medicine), and early (including research students) and mid-career stage researchers based across a varied geographical area (Switzerland, Australia, Sweden).

Sample

We included a purposive sample of all matches from the men's FWC22 and the women's FWWC23, where the same national teams played against each other to reduce geographical and cultural bias when comparing data between teams of men and women. Consequently, eight matches were included. The national teams playing each other in both FWCs were Spain versus Costa Rica, Australia versus Denmark, The Netherlands versus USA and France versus Morocco.

Sample size calculation

G* Power (V.3.1.9.7—Germany) was used a priori to calculate the sample size of headers required to assess the difference in heading descriptors with a categorical dependent variable. Using an effect size of 0.25, α-error of 0.05, and power of 0.95, a minimum sample size of 109 headers were required per group. For heading descriptors with a continuous dependent variable, a minimum of 88 headers per group were required using an effect size of 0.5, α-error of 0.05 and power of 0.95.

Video analysis process

All head impact types

The first round of coding included recording all headers, attempted headers, unintentional ball-head impacts and other head impacts using full match footage from four different camera angles during each respective World Cup using the following definitions:

- Header: a head-to-ball contact where the player makes a deliberate movement to redirect the trajectory of the ball (using their head).
- Attempted header: a deliberate attempt by a player to make head contact with the ball but without any head-to-ball contact actually occurring (eg, a mistimed jump).
- Unintended ball-to-head impact: where the player does not appear to be deliberately trying to redirect

the ball (eg, ball impact with a player's face or head when the ball is played at short range or ball impact to the back of a player's head).
- Other head impact: any impact to a player's head or face which is not from a ball (eg, head-to-head, elbow-to-head, ground-to-head, goalpost-to-head contact).

In addition, medical assessment of a potential head injury was recorded based on whether the player was assessed by the team's medical staff following a head impact (coded as either yes or no). Referee sanctions were also collected, which included whether a red or yellow card was given to any player following a head impact event (coded as red/yellow card awarded to the player with head impact or the other player).

Headers only

A second round of coding was performed to code only the identified headers for specific descriptors related to the header as well as the technical performance of each header. No other type of head impact was included in this subsequent round of recording. The full list of heading descriptors is defined in table 1.

Data collection and calculation of inter-rater and intra-rater reliability

A training session was performed between the project lead (KP—a researcher experienced in video coding of head impacts in football)[18–20] and a second researcher, a research student, (FO) using a prespecified coding sheet. The second researcher (FO) analysed all match videos using high-definition footage recorded at 24 frames per second. A third experienced researcher (JG)[4] then independently analysed two random matches (one men's and one women's match) to code head impact events and determine inter-rater reliability of head impact coding. Intra-rater reliability of heading descriptors was calculated for one men's and one women's match for all heading descriptors coded by the second researcher (FO). Both inter-rater and intra-rater reliability were independently calculated by the project lead (KP).

Data analysis

All statistical analyses were performed in STATA V.18 (College Station, Texas). Descriptive data including counts, means and/or percentages for heading descriptors as well as incidence rate (IR) per 1000 match hours and incidence rate ratios (IRR) for respective head impact events, heading descriptors and heading performance descriptors are presented. The IR per 1000 match hours was calculated as follows: (number of events/hour of match exposure)×1000). The match exposure was calculated by using the following equation number of matches (4 or 8)×number of players on the field (22)×duration of the match (1.5 hours)=(132 hours or 264 hours).

Differences between men and women for count data including head impact types, heading descriptors and heading performance descriptors were calculated using negative binomial regression analyses with men as the reference group. Data are presented as IRR and 95% CI Furthermore, the difference between men and women for timing of eye closure (continuous data) was calculated using an independent t-test. Cohen's d, an effect size measurement for the t-test, is reported with interpretation of <0.2 (small effect size), 0.3–0.5 (medium effect size) and 0.6–0.8 (large effect size).[21] Statistical significance for the α-error was set at p≤0.05.

Inter-rater and intra-rater reliability of coding was assessed using two-way mixed effects intraclass correlation coefficient (ICC). Based on the 95% CI of the ICC estimate, values <0.50 were indicative of poor reliability, 0.51–0.75 (moderate), 0.76–0.90 (good) and >0.91 (excellent).[22] Data analysis and presentation of results are consistent with A CHecklist for statistical Assessment of Medical Papers statement.[23]

RESULTS

Reliability

The results for the inter-rater reliability were deemed as excellent (>0.90) in both FWC22 and FWWC23 for coding of the different types of head impacts. Intra-rater reliability demonstrated good–excellent reliability (>0.85) for all heading descriptors except for the following descriptors block/clearance/deflection/interference and contact from the back which demonstrated moderate reliability (>0.65) (online supplemental table 1).

Head impact type

All head impact types: Across all eight matches in the FWC22 and FWWC23, there were 973 head impact events involving 200 players (FWWC23=102, FWC22=98), of which 845 (87%) were headers, 93 (10%) were attempted headers and 35 (4%) were unintentional head impacts. The number of head impacts observed per player in the FWWC23 ranged from 0 to 16 (mean 4.6 per player per match), with between 10 and 15 players (mean 12.8) experiencing at least one type of head impact per team per match. In the FWC22, the number of head impacts ranged from 0 to 23 (mean 5.0 per player per match), with between 10 and 14 players (mean 12.3) experiencing at least one type of head impact per team per match. The incidence rate of head impacts in the FWWC23 was 3614 per 1000 match hours (95% CI 3611 to 3617) and 3758/1000 hour (95% CI 3733 to 3783) in the FWC22 (IRR: 1.04, 95% CI 0.84 to 1.09, p=0.54), table 2. Differences between men and women for head impact type were all non-significant (table 2).

Headers only: the incidence rate of headers in the FWWC23 was 3098/1000 hour (95% CI 3087 to 3109) and 3303/1000 hour (95% CI 3278 to 3328) in the FWC22 (IRR 1.07, 95% CI 0.91 to 1.19, p=0.20). No significant differences were found between men and women within each playing position (table 2) with defenders performing more headers than midfielders and forwards for both men and women. Goal keepers were not observed to head the ball in any of the eight

Table 1 Heading descriptors and their definitions recorded for all headers using the 'FIFA Football Language'[36] where possible*

Descriptor	Definition	Coding options
Demographic descriptors (player performing the header)		
Player position	Player position relates to the position the player performing the header was in at kick-off, or when initially substituted into the match.	**Goalkeeper**—Player plays in goal. **Defender**—Includes central defenders and full backs. **Midfielder**—Includes defensive, attacking, central and other midfielders. **Forward**—Includes centre-forwards and wingers.
Heading descriptors		
Ball delivery	Describes how the ball was delivered prior to the header.	**Free play**—The ball is in free flow motion anywhere on the pitch. **Corner**—Grounded stationary ball is played from the corner area to restart play. **Throw in**—The ball is thrown overhead with both hands from the touchline to restart play. **Free kick**—Grounded stationary ball is played from the position where the free kick was awarded by the referee to restart play. **Goal kick**—Grounded stationary ball is played from the goal area. **Punt**—Goalkeeper drops the ball from his/her hand and kicks the ball with his/her foot before it hits the ground. **Long ball**—Ball flight mimics that of a goal kick such as a free kick around the 18-yard area, or any other long kick from the goalkeeper or other out-field player.
Purpose of header*	Describes the intended purpose or outcome of the header.	**Block**—An opposition player blocks a distribution event from reaching its intended target, the player blocking the distribution does not attempt to win possession themselves. **Clearance**—An attempt by a player to get the ball out of the danger zone when there is pressure. **Deflection**—A defender intervenes against a player's attempt at goal and directs the ball's trajectory beyond the goal line or is prevented by doing so by hitting the goal frame or another player's action at the goal line. **Interception**—An opposition player stops a distribution event in open play or set play from reaching its intended target with the aim of retaining possession for themselves or their team **Shot**—An intention of scoring a goal that was unsuccessful. **Goal-** Goal scored via a header. **Pass**—Action with a player's head to redirect the ball to a teammate. **Self-serve**—The player tries to gain control over the ball themselves.
Contested header	Two or more players were observed to compete for a header in close enough proximity that physical contact between any body part of the players is possible but not necessarily observed.	**Yes**—Two or more players were observed to compete for the header. **No**—Only the player heading the ball was observed.
If contested header was coded 'yes' the presence of an aerial duel was further coded		
	Aerial duel*: Two or more players competing for a ball that is above shoulder height; where at least one player is off the ground and is being physically challenged by an opposition player.	**Yes**—A contested header where at least one of the players was off the ground. **No**—All players competing for the ball within reach were grounded.
Involvement of other players	Other players were observed within one arm's length distance of the player performing the header	**Yes**—At least one other player was observed within one arm's length of distance at the time of the header. *NB* If two or more players were within one arm's length of distance at the time of the header, the number of players was also recorded. **No**—No other player was observed within one arm's length of the player heading the ball at the time of heading.
When involvement of other players was coded 'yes' the following descriptors were also coded		
	Interference: Another player interfered with the movement of the player performing the header without duelling for the ball.	**Yes**—Interference of another player was observed. **No**—No interference was observed.

Continued

Table 1 Continued

Descriptor	Definition	Coding options
	Physical contact: Physical contact between the player performing the header and any other player was observed.	**Yes**—Physical contact between players was observed. **No**—No physical contact was observed.
If physical contact was observed between players further branching descriptors included:		
	Early contact: Contact between players was established prior to header being performed.	**Yes**—Physical contact was established before the first player reached for the ball. For example, before leaving the ground in a jumping header. **No**—No physical contact was seen prior the header being performed.
	Late contact: Contact between players was established within 0.5 seconds after the header was performed.	**Yes**—Physical contact was observed. **No**—No late contact was observed.
	Significant contact: The observed contact was significant enough to alter the movement of the player performing the header.	**Yes**—The physical contact altered the movement of the player performing the header. **No**—No physical contact or the contact did not seem to alter the movement of the player performing the header.
	Contact from behind: Physical contact in the back of the player performing the header was observed	**Yes**—Physical contact from the back was observed. **No**—No contact from the back was observed.
Technical descriptors		
Controlled header	The player demonstrates a level of control in the redirection of the ball. For example, if a player redirects the ball towards the goal or a teammate.	**Yes**—The player demonstrates control of the redirection of the ball. **No**—The player did not demonstrate control of the redirection of the ball.
Timing of eye closure	Timing of when the player performing the header closed their eyes prior to the ball making contact with their head contact.	This characteristic was calculated using number of frames in the match video in slow motion from the frame when the player's eyes first closed until the frame where the ball is most proximate to the head (ie, higher number of frames means the player's eyes closed earlier prior to head-to-ball contact).
Point of head contact	The area of the head where the ball makes contact during a header. *NB this was determined by visual confirmation and by the change of trajectory of the ball*.	**Forehead**—from the eyebrows to hairline (or approximate hairline where one does not exist). **Face**—frontal area from eyebrows to the chin. **Top**—start of hairline to just past the highest point of the head (vertex or crown area). **Side**—area around the ears. **Back**—area below the crown and between both ears in width.
Back extension	Back of the player performing the header was observed to extend prior to the header.	**Yes**—A degree of back extension was observed. **No**—No back extension prior to the header was observed.
Upper body usage	Upper body movement of the player performing the header prior to the header	**Yes**—Movement of the upper body was observed. **No**—No upper body movement was observed.

matches. No referee sanctions were observed that were associated with a header.

Heading descriptor data

Differences between men and women for ball delivery method were observed with men being more likely to head the ball from a long ball (IRR 2.55, p=0.002) or during free play (IRR 1.16, p=0.01) and women being more likely to head the ball from corners (IRR 0.47, p=0.008) and goal kicks (IRR 0.28, p=0.001). Regarding the purpose of the header, men were more likely to use their head to pass the ball (IRR 1.64, p=0.002), whereas women were more likely to use a header to intercept play (IRR 0.01, p=0.01) table 3.

Technical performance descriptors

In terms of the differences between men and women for technical performance descriptors, when compared with men, women performed less controlled headers (IRR 1.20, p=0.01) and used their upper body less (IRR 1.29, p=0.005). In terms of point of head contact, women were more likely to use the top of their head to head the ball (IRR 0.91, p=0.004), whereas men were more likely to use their forehead (IRR 2.36, p=<0.001). table 4.

From 222 headers (FWWC23 n=111 and FWC22 n=111,) the mean number of frames showing the player's eyes closed prior to the header was 1.56 (95% CI 1.41 to 1.70) for men and 1.91 (95% CI 1.74 to 2.07) for women, indicating that women closed their eyes earlier before the

Table 2 Absolute (n), relative frequencies (%), incidence rates and statistical analyses of each head impact type comparing FWC22 and FWWC23 matches

Head impact type	FWWC23 (W) n=477, IR 3614	FWC22 (M) n=496, IR 3758	Incidence rate ratio (95% CI)*	P value
Headers				
Total (n, %),	409, 85.7%	436, 87.7%	1.07	0.2
Incidence rate	3098/1000 hour	3303/1000 hour	(0.91 to 1.19)	
Mean/player/match§	4.6	5.0		
Headers per playing position				
Defenders				
Total number of headers (n, %)	208, 52.6%	214, 49.7%	1.03	0.39
Incidence rate	1576/1000 hour	1621/1000 hour	(0.80 to 1.12)	
Headers per defender (n)	6.5	6.7		
Midfielders				
Total number of headers (n, %)	110, 27.8%	125, 29.0%	1.14	0.71
Incidence rate	833/1000 hour	946/1000 hour	(0.80 to 1.36)	
Headers per midfielder (n, %)	4.6	5.2		
Forwards				
Total number of headers (n)	77, 19.5%	92, 21.3%	1.20	0.51
Incidence rate	583/1000 hour	697/1000 hour	(0.81 to 1.48)	
Headers per forward (n)	3.2	3.8		
Unable to code‡	14	5		
Attempted headers				
Total (n, %),	49, 10.3%	44, 8.9%	0.90	0.59
Incidence rate	371/1000 hour	333/1000 hour	(0.59 to 1.34)	
Mean/player/match	0.6	0.5		
Unintentional ball-to-head contact				
Total (n, %),	11, 2.3%	6, 1.2%	0.54	0.2
Incidence rate	83/1000 hour	45/1000 hour	(0.20 to 1.43)	
Mean/player/match§	0.1	0.1		
Other head impacts				
Total (n, %),	8, 1.7%	10, 2.0%	1.25	0.68
Incidence rate	61/1000h	76/1000 hour	(0.48 to 3.09)	
Mean/player/match§	0.1	0.1		
Medical assessment of potential head injury				
Total (n)	2	1	0.50	0.48
Incidence rate	16/1000 hour	8/1000 hour	(0.18 to 3.79)	
Mean/player/match§	0.02	0.01		

*IRR calculated using negative binomial regression (with men as the reference group).
‡Number of each descriptor that could not be coded (these values were excluded from the percentage calculation).
§Mean headers per player per match was calculated for number of players on the field at the time of the header/four matches.
FWC22, FIFA World Cup; FWWC23, FIFA Women's World Cup; IR, incidence rate per 1000 match hours; M, men; W, women.

header when compared with men (t(220) 3.17, Cohen's d 0.41, p=0.002). *NB* 623 headers (73%) were unable to be coded for this descriptor due to an unclear view of the player's face in at least one frame from when the eyes started to close and the ball making contact.

DISCUSSION

This descriptive video analysis study aimed to explore the incidence of headers, attempted headers and other head impacts performed during a purposive sample of FWC and FWWC matches. Our results did not support our first

Table 3 Absolute (n), relative frequencies (%), incidence rates and statistical analyses of heading descriptors between men and women

Descriptor	FWWC2023 (W) n=409	FWC2022 (M) n=436	Incidence rate ratio (95% CI)†	P value*
Ball delivery method (n, %, IR)				
Free play	218, 58.4% 1651/1000 hour	253, 72.3% 1917/1000 hour	1.16 (1.00 to 1.43)	0.01*
Corner	38, 10.2% 287/1000 hour	18, 5.0% 136/1000 hour	0.47 (0.25 to 0.94)	0.008*
Goal kick	58, 15.5% 439/1000 hour	16, 4.4% 121/1000 hour	0.28 (0.14 to 0.59)	0.001*
Throw-in	24, 6.4% 182/1000 hour	21, 5.8% 159/1000 hour	0.87 (0.39 to 2.09)	0.72
Long ball	13, 7.2% 98/1000 hour	33, 9.2% 250/1000 hour	2.55 (1.03 to 6.59)	0.002*
Free kick	14, 3.5% 106/1000 hour	15, 4.2% 115/1000 hour	1.08 (0.35 to 3.46)	0.79
Punt	8, 2.1% 61/1000 hour	4, 1.1% 30/1000 hour	0.49 (0.07 to 3.86)	0.27
Unable to code‡	36	76		
Purpose of header (n, %)				
Interception	105, 33.0% 795/1000 hour	87, 24.4% 659/1000 hour	0.83 (0.49 to 1.12)	0.01*
Pass	105, 33.0% 795/1000 hour	172, 48.2% 1303/1000 hour	1.64 (1.15 to 1.87)	0.002*
Clearance	70, 22.0% 530/1000 hour	64, 17.9% 485/1000 hour	0.92 (0.50 to 1.29)	0.16
Shot	20, 6.3% 152/1000 hour	11, 3.6% 83/1000 hour	0.55 (0.24 to 1.38)	0.11
Block	9, 2.8% 68/1000 hour	6, 1.7% 45/1000 hour	0.66 (0.13 to 2.63)	0.32
Self-serve	5, 1.6% 38/1000 hour	12, 3.4% 91/1000 hour	2.39 (0.39 to 11.53)	0.14
Deflection	4, 1.3% 30/1000 hour	3, 0.8% 23/1000 hour	0.77 (0.6 to 8.04)	0.60
Goal scored	3, 0.7% 23/1000 hour	0, 0.0% 0/1000 hour	–	–
Unable to code‡	88	81		
Contested headers (n,%, IR)	139, 34.0% 1053/1000 hour	141, 32.3% 1068/1000 hour	1.01 (0.75 to 1.20)	0.61
Aerial duel (n,%, IR)	133, 95.7% 1008/1000 hour	133, 94.3% 1008/1000 hour	1.00 (0.78 to 1.25)	0.60
Involvement of other players (n, %, IR)	216, 52.8% 1636/1000 hour	203, 46.6% 1538/1000 hour	0.94 (0.73 to 1.06)	0.07
Interference (n, %, IR)	27, 12.5% 205/1000 hour	38, 18.7% 288/1000 hour	1.40 (0.91 to 2.44)	0.08
Physical contact (n, %, IR)	182, 84.2% 1379/1000 hour	187, 92.1% 1417/1000 hour	1.03 (0.82 to 1.43)	0.42
Early contact	47, 25.7% 356/1000 hour	43, 22.6% 326/1000 hour	0.92 (0.64 to 1.47)	0.90
Late contact	11, 6.0% 83/1000 hour	7, 4.7% 53/1000 hour	0.64 (0.26 to 1.74)	0.42

Continued

Table 3 Continued

Descriptor	FWWC2023 (W) n=409	FWC2022 (M) n=436	Incidence rate ratio (95% CI)†	P value*
Significant contact	98, 54.1% 742/1000 hour	101, 53.7% 765/1000 hour	1.03 (0.83 to 1.44)	0.37
Contact from behind	26, 14.2% 197/1000 hour	36, 18.9% 273/1000 hour	1.39 (0.89 to 2.43)	0.13

*p≤0.05.
†IRR calculated using negative binomial regression (with men as the reference group).
‡Unable to code = number of each descriptor that could not be coded and are excluded from the percentage calculation.
FWC22, FIFA World Cup 2022; FWWC23, FIFA Women's World Cup 2023; IR, incidence rate per 1000 match hours.

hypothesis that professional women would perform fewer headers than men in their respective World Cups. While women did record slightly fewer head impact events than men (n=477 compared with n=496, IRR 1.04) as well as fewer headers (n=409, n=436, IRR 1.07), these differences were not significant. The mean number of headers per player per match was also very similar (n=4.6, n=5.0).

We also aimed to explore the difference in heading descriptors, including technical performance, between men and women, where our second hypothesis was supported that there were differences in heading technique between men and women. We found that, in our study, men performed more controlled headers (IRR1.20, p=0.01) as well as a higher proportion of headers using their foreheads (IRR 2.36, p=<0.001) and used their upper body more often during the header (IRR 1.29, p=0.005) when compared with women. Men and women also differed in some ball delivery methods with men performing more headers from free play (IRR 1.16, p=0.01) and long balls (IRR 2.55, p=0.002), and women performing more headers from corners (IRR 0.47, p=0.008) and goal kicks (IRR 0.28, p=0.001). The

Table 4 Absolute (n), relative frequencies (%), incidence rates and statistical analysis of heading performance

Descriptor	FWWC23 (W) n=409	FWC22 (M) n=436	Incidence rate ratio (95% CI)†	P value*
Controlled header (n, %, IR)	299, 73.3% 2265/1000 hour	360, 82.9% 2727/1000 hour	1.20 (0.97 to 1.32)	0.01*
Unable to code‡	1	2		
Point of head contact				
Forehead	41, 12.9% 311/1000 hour	97, 27.0% 735/1000 hour	2.36 (1.44 to 3.00)	<0.001*
Side	62, 19.6% 470/1000 hour	72, 20.1% 545/1000 hour	1.16 (0.69 to 1.50)	0.89
Top	205, 64.7% 1553/1000 hour	186, 51.8% 1409/1000 hour	0.91 (0.69 to 0.93)	0.004*
Back	8, 2.5% 61/1000 hour	4, 1.1% 30/1000 hour	0.49 (0.07 to 2.60)	0.16
Face	1, 0.3% 8/1000 hour	2, 0.6% 16/1000 hour	2.00 (0.34 to 2.93)	0.64
Unable to code‡	92	75		
Back extension (n, %, IR)	135, 47.0% 1023/1000 hour	154, 51.8% 1167/1000 hour	1.14 (0.87 to 1.39)	0.25
Unable to code‡	122	139		
Upper body usage (n, %, IR)	244, 79.7% 1848/1000 hour	314, 87.7% 2379/1000 hour	1.29 (0.93 to 1.30)	0.005*
Unable to code‡	103	78		

IR—incidence rate per 1000 match hours.
*p≤0.05.
†IRR calculated using negative binomial regression (with men as the reference group).
‡Unable to code = number of each descriptor that could not be coded and are excluded from the percentage calculation.
FWC22, FIFA World Cup 2022; FWWC23, FIFA Women's World Cup 2023.

purpose of the header also differed in that men were more likely to perform a header to pass the ball (IRR 1.64, p=0.002) and women more likely to intercept play (IRR 0.83, p=0.01). Finally, we found that women closed their eyes earlier before the header (p=0.002) when compared with men.

The most common type of head impact observed in these eight matches were headers with the proportion of head impact type being comparable between men and women. A 2022 systematic review of 59 studies on the factors determining head impacts and their magnitude in football reported that exposure to head impacts differed between men and women and between children and adults, with women on average experiencing higher accelerations but less frequent impacts.[24] While head impact magnitude was not recorded in our study, our results suggest that at the professional level, men and women are exposed to similar numbers of head impact events, including a total number of headers (men's IR: 3303, women's IR: 3098). This is also consistent with findings in previous men's (IR: 2509)[20] and women's (IR: 2601)[4] FWC and FWWC (2018 and 2019, respectively). In terms of the purpose of the header, the high number of passes and interceptions seen in matches have been reported in an earlier study in men, where 36% of headers were a pass and 46% were an interception[6] compared with 48% and 24% in our study. The differences in proportions between these two studies are likely related to the difference in recording options, with the earlier study having four options for this descriptor (pass, shot, interception, clearance)[6] compared with eight options in our study (pass, shot, interception, clearance, block, self-serve, deflection and goal scored). However, our study is understood to be the first to report these data in women with our results showing that women also seem to perform headers to pass (33%) and intercept the ball (33%), although the proportion of passing headers in our study was higher in men (48%, IRR 1.64, p=0.002). Furthermore, women were observed to perform more headers than men from corners, and goal kicks which have been shown to have higher head impact magnitudes than other types of ball deliveries, such as free play and throw-ins.[25] While in both men and women, the most common mechanism for head injuries (including concussion) is from player-to-player contact, earlier studies have reported that women are more likely to be injured by the ball itself when compared with men,[17 26] whereas in men, this mechanism of injury is far less common.[27–29] The higher number of headers from corners, and goal kicks in women might be a contributing factor to the differences in injury risk from the ball between men and women. However, it should be noted that while men and women both completed the most headers during free play (72% and 58%, respectively), men performed more headers from long balls than women (IRR 2.55, p=0.002). Headers from corners, goal kicks and long balls are often considered high-velocity headers, with the most recent heading guidelines in England[9] currently restricting high-velocity headers to a maximum of 10 per week for all football players including professional players.

It has also been hypothesised that the increased rate of eye closure before a header in women might explain the higher rates of head injury caused by the ball in women's football,[11 13] given that lack of anticipation of when the ball is going to make contact with the head can lead to higher head impact magnitudes (in part due to reduced activation of the neck musculature).[30] Early eye closure could also increase the chances of missing an opponent player's movement, resulting in an increased risk of head-to-head contact, for example. In our study, women closed their eyes earlier than men prior to the header (mean 1.91 vs 1.56 frames, which is a difference of 22%; Cohen's d 0.41, p=0.002). Based on our 24 frames per second footage, this difference in eye closure could equate to around 15 ms, and with an incoming ball travelling at 80 km/hour (a speed which has been recorded from balls delivered from a goal kick, shot or corner),[31] this could be equivalent to closing the eyes when the ball is ~33 cm further away from the player's head. While this scenario provides some context to this finding, it should be interpreted with caution given the novelty of coding for eye closure and the limited number of headers that could be analysed for this descriptor. Aside from possibly contributing to an increased risk of getting injured by the ball in women, early eye closure is also one indicator of poor heading technique.[14] Football coaches involved in collegiate, high school and competitive football assisted in the creation of a 14-step heading performance checklist with the first item related to eye closure ('maintain eye contact with ball up until physical contact is made with the player and ball').[14] A pilot study which evaluated Behavior Skills Training as a method to teach correct heading technique to girls, demonstrated an improvement in players being able to keep their eyes open for longer (with less time between eye closure and ball-head contact during a header) following the intervention, suggesting that being able to maintain eye contact with the ball is a skill that can be taught and learnt.[14] Other items in this checklist were head contact location, the use of the upper body and back extension.[14] Men in our study completed more headers with their forehead when compared with women (IRR 2.36, p=<0.001). Using the forehead to head, the ball is generally considered 'proper technique' with research demonstrating that an improper technique of heading the ball (ie, using the top or side of the head) results in a larger peak rotational velocity than proper technique (ie, forehead).[32] Active engagement of the neck musculature during heading is facilitated by being able to track the trajectory of the ball and using the forehead to make timely contact with the ball (balls received on the side or top of the head make ball tracking and subsequent muscle activation more challenging). Furthermore, players need to be able to increase their effective mass when executing a header, with effective mass being defined as the mass of the player which is able to oppose the force of the ball on head-to-ball contact.[33] It is suggested that women have

lower effective mass than men due to weaker neck musculature, which can lead to higher head impact magnitudes during heading.[30 34] Furthermore, players that are able to maintain eye contact with the ball and track its trajectory right up until head-to-ball contact means that they are better able to move and position their body to safely and more effectively execute the header, which may include the use of back extension (rather than trying to control the ball with their neck only). Players not only need to be able to appropriately position their upper body for balance during the header but also to protect their space during an aerial or other physical duel. In our study, men were more likely to use their upper body than women when performing the header (IRR 1.29, p=0.005). A lack of protective upper body positioning has been suggested as a contributing factor to the higher rates of concussion observed in women when compared with men.[11] However, given that women and girls are more likely to report a lack of formal heading technique training[16] as well as being more likely to specialise in football later than boys and have reduced access to elite football training environments and specialist school football programmes,[35] it is likely that these factors are more important than innate biological differences between men and women.[11] Therefore, further research to explore technical differences in heading performance between men and women, boys and girls, across all levels of football as well as further exploration of the contributing factors associated with any observed differences is highly recommended.

In our study, there were only three events where the country's medical team entered the field of play after a head impact. Two in women with one being an unintentional ball-to-head impact and the other from player-to-player contact during an aerial duel. There was one event in men from player-to-player contact during an aerial duel. Therefore, to explore whether timing of eye closure or the use of protective body positioning can influence head injury risk in men's and women's football, a study sufficiently powered for these outcomes is recommended.

Research/policy implications

The main findings from this study indicate that women are exposed to similar numbers of headers to men during professional football tournaments. However, when compared with men, women performed less controlled headers, performed less headers with their forehead, closed their eyes earlier before the header and were less likely to use their upper body. This information could be used to inform sex-specific coaching frameworks and heading guidelines to support players to develop technical proficiency in heading skill development, which may also have implication for mitigating the head injury risk and burden associated with heading.

Limitations

There are a number of limitations in our study that should be acknowledged. Although the total number of headers as well as number of headers for each studied descriptor exceeded the sample size calculation for both men and women, there were some descriptors, such as timing of eye closure, that were difficult to see despite the availability of four camera angles of high-resolution footage. This meant that a moderate to large proportion of headers for both men and women for a number of descriptors were unable to be coded mainly due to the camera angles being blocked by other players around the person performing the header, the movement of the player themselves and/or the angles of footage. Therefore, the results should be cautiously interpreted relative to the proportion of headers, which were able to be coded for each descriptor. Furthermore, the sample size calculation conducted a priori as well as statistical analyses did not account for any clustering within players. Given the variation in the number of head impact types observed by individual players within each team, it is possible that this could influence the findings. Another limitation of this study is the generalisability of the findings to other populations within football (such as players with lower levels of experience and skill levels as well as different age groups), particularly as this is believed to be the first study to explore many of these technical descriptors of heading performance in real-time match-play. Therefore, replicating this study in different populations of players is encouraged.

CONCLUSION

This study provides new information regarding differences in the technical performance of headers between professional men and women. Technical heading descriptors such as eye closure, point of head contact and use of the upper body could be important factors to include in heading coaching frameworks, which can be addressed in training to improve heading performance particularly in women and girls. Future heading research should include technical heading descriptors to explore whether heading technique has any relationship with head impact magnitude and mechanism of head injuries in football.

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REFERENCES

1 Alia MFM, Katisb A, Patsikab G, *et al*. Goal scoring characteristics in soccer: are they technique and time dependent? *Asia Pac J Adv Bus Soc Stud* 2015;1:186–93.
2 UEFA. UEFA Euro- team stats. 2024. Available: https://www.uefa.com/uefaeuro/history/seasons/2020/statistics/teams/goals/?sortBy=goals_scored_head&order=desc [Accessed 6 Apr 2024].
3 Peek K, Duffield R, Cairns R, *et al*. Where are We Headed? Evidence to Inform Future Football Heading Guidelines. *Sports Med* 2023;53:1335–58.
4 Georgieva J, Arnold EJ, Peek K, *et al*. The incidence and characteristics of heading in the 2019 FIFA Women's World Cup™. *Sci Med Foot B* 2024;2024:1–8.
5 Peek K, Ross A, Andersen TE, *et al*. Heading in football: a systematic review of descriptors, definitions, and reporting methods used in heading incidence studies. *Sci Med Footb* 2024;2024:1–18.
6 Sarajärvi J, Volossovitch A, Almeida CH. Analysis of headers in high-performance football: evidence from the English Premier League. *Int J Perform Anal Sport* 2020;20:189–205.
7 Weber J, Ernstberger A, Reinsberger C, *et al*. Video analysis of 100 matches in male semi-professional football reveals a heading rate of 5.7 headings per field player and match. *BMC Sports Sci Med Rehabil* 2022;14:132.
8 Weber J, Reinsberger C, Krutsch V, *et al*. 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 Foot B* 2023;7:307–14.
9 Football Association (England). Heading guidance. 2023. Available: https://www.englandfootball.com/participate/learn/Brain-Health/Heading-in-Football
10 Yang YT, Baugh CM. US Youth Soccer Concussion Policy: Heading in the Right Direction. *JAMA Pediatr* 2016;170:413–4.
11 Peek K, Fraser K, Yearwood GMH, *et al*. Women, concussion and disputing an old myth: the game of football is not "unsuitable for females." *Br J Sports Med* 2024;58:297–8.
12 Clark J, Betz B, Borders L, *et al*. Vision training and reaction training for improving performanceand reducing injury risk in athletes. *J Sports Perform Vis* 2020;2:e8–16.
13 Clark JF, Elgendy-Peerman HT, Divine JG, *et al*. Lack of eye discipline during headers in high school girls soccer: A possible mechanism for increased concussion rates. *Med Hypotheses* 2017;100:10–4.
14 Quintero LM, Moore JW, Yeager MG, *et al*. Reducing risk of head injury in youth soccer: An extension of behavioral skills training for heading. *J Appl Behav Anal* 2020;53:237–48.
15 Erkmen N. Evaluating the heading in professional soccer players by playing positions. *J Strength Cond Res* 2009;23:1723–8.
16 Parsanejad E, McKay MJ, Ross AG, *et al*. Heading in Football: insights from stakeholders in amateur football. *Sci Med Foot B* 2024;8:212–21.
17 Blyth RJ, Alcock M, Tumilty DS. Why are female soccer players experiencing a concussion more often than their male counterparts? A scoping review. *Phys Ther Sport* 2021;52:54–68.
18 Peek K, Meyer T, Beaudouin F, *et al*. Heading incidence in boys' football over three seasons. *Sci Med Foot B* 2021;5:175–80.
19 Peek K, Vella T, Meyer T, *et al*. The incidence and characteristics of purposeful heading in male and female youth football (soccer) within Australia. *J Sci Med Sport* 2021;24:603–8.
20 Roman I, McKay M, Peek K. Head impact events in youth football in India and Australia, compared to FIFA Men's World Cup matches. *J S A M S Plus* 2023;2:100029.
21 Cohen J. Statistical power analysis. *Curr Dir Psychol Sci* 1992;1:98–101.
22 Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med* 2016;15:155–63.
23 Mansournia MA, Collins GS, Nielsen RO, *et al*. A CHecklist for statistical Assessment of Medical Papers (the CHAMP statement): explanation and elaboration. *Br J Sports Med* 2021;55:1009–17.
24 Basinas I, McElvenny DM, Pearce N, *et al*. A Systematic Review of Head Impacts and Acceleration Associated with Soccer. *Int J Environ Res Public Health* 2022;19:5488.
25 Caccese JB, Lamond LC, Buckley TA, *et al*. Reducing purposeful headers from goal kicks and punts may reduce cumulative exposure to head acceleration. *Res Sports Med* 2016;24:407–15.
26 Dave U, Kinderknecht J, Cheng J, *et al*. Systematic review and meta-analysis of sex-based differences for concussion incidence in soccer. *Phys Sportsmed* 2022;50:11–9.
27 Beaudouin F, Aus der Fünten K, Tröß T, *et al*. Head injuries in professional male football (soccer) over 13 years: 29% lower incidence rates after a rule change (red card). *Br J Sports Med* 2019;53:948–52.
28 Beaudouin F, der Fünten KA, Tröß T, *et al*. Time Trends of Head Injuries Over Multiple Seasons in Professional Male Football (Soccer). *Sports Med Int Open* 2019;3:E6–11.
29 Beaudouin F, Aus der Fünten K, Tröß T, *et al*. Match Situations Leading to Head Injuries in Professional Male Football (Soccer)-A Video-Based Analysis Over 12 Years. *Clin J Sport Med* 2020;30 Suppl 1:S47–52.
30 Perkins RA, Bakhtiarydavijani A, Ivanoff AE, *et al*. Assessment of brain injury biomechanics in soccer heading using finite element analysis. *Brain Multphys* 2022;3:100052.
31 Tierney GJ, Power J, Simms C. Force experienced by the head during heading is influenced more by speed than the mechanical properties of the football. *Scand J Med Sci Sports* 2021;31:124–31.
32 Harriss A, Johnson AM, Walton DM, *et al*. Head impact magnitudes that occur from purposeful soccer heading depend on the game scenario and head impact location. *Musculoskelet Sci Pract* 2019;40:53–7.
33 Babbs CF. Biomechanics of heading a soccer ball: implications for player safety. *Sci World J* 2001;1:281–322.
34 Peek K, Elliott JM, Orr R. Higher neck strength is associated with lower head acceleration during purposeful heading in soccer: A systematic review. *J Sci Med Sport* 2020;23:453–62.
35 Söderström T, Garn AC. Sport specialization in Swedish football players: Investigating a model of antecedents and outcomes. *Eur J Sport Sci* 2023;23:1868–76.
36 FIFA. Study the FIFA Football Language Zurich, Switzerland, 2023. Available: https://www.fifatrainingcentre.com/en/resources-tools/football-language/ [Accessed 27 Sep 2023].