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Beaudouin, Florian; Gioftsidou, Asimenia; Larsen, Malte Nejst; Lemmink, Koen; Drust, Barry; Modena, Roberto; Espinola, Javier Ramos; Meiu, Mihai; Vouillamoz, Marc; Meyer, Tim

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The UEFA Heading Study: Heading incidence in children's and youth' football (soccer) in eight European countries

Florian Beaudouin[1] | **Asimenia Gioftsidou**[2] | **Malte Nejst Larsen**[3] | **Koen Lemmink**[4] | **Barry Drust**[5] | **Roberto Modena**[6] | **Javier Ramos Espinola**[7] | **Mihai Meiu**[8] | **Marc Vouillamoz**[9] | **Tim Meyer**[1]

[1]Institute of Sports and Preventive Medicine, Saarland University, Saarbrücken, Germany

[2]Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece

[3]Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark

[4]Center of Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands

[5]Sport and Exercise Sciences, John Moores University, Liverpool, UK

[6]CeRiSM Research Center Sport Mountain and Health, University of Verona, Verona, Italy

[7]Investigacion Puerta Hierro, Madrid, Spain

[8]Romanian Football Federation, Bucharest, Romania

[9]Union des Associations Européennes de Football (UEFA), Nyon, Switzerland

Correspondence
Florian Beaudouin, Institute of Sports and Preventive Medicine, Saarland University, Campus, Building B 8-2, 66123 Saarbrücken, Germany.
Email: florian.beaudouin@uni-saarland.de

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To assess the real-life magnitude of the heading incidence in children's and youth' football in eight European countries with different "football cultures," a cross-sectional observational design, in which one match per team in 480 different teams from eight European countries (2017/18-2018/19), was recorded by video. One training session was recorded in 312 teams. Clubs with Under-10, Under-12 (female/male/mixed), and Under-16 female and male teams were eligible to participate. Heading frequencies and types were analyzed. Results are presented as headers per match/training and per team. Incidence rates (IR) per 1000 match/training hours were calculated. Under-10 teams carried out the lowest average number of headers per match (8.8), followed by Under-16 female (17.7), Under-12 (18.4), and Under-16 male (35.5). Total number of headers per match and team varied between countries. 80% of the total number of headers were single intentional headers, 12% heading duels, 3% unintentional headers by getting hit, and 5% others (trends apparent in all age groups). Three head injuries occurred during match play corresponding to an IR of 0.70 (95% CI, 0.23-2.16). The lowest number of headers per training and team was found in Under-10 (21.3), followed by Under-16 females (34.1), Under-12 (35.8), and Under-16 males (45.0). In conclusion, this large-scale study presents novel data about the number and type of headers in youth' football throughout Europe. A more precise understanding of the heading incidence, specifically in young players, is mandatory for the debate of restrictions on heading in youth football.

KEYWORDS
adolescents, head injury, heading, risk

1 | INTRODUCTION

Football is the only sport, in which players purposefully use the head to play the ball.[1] In recent years, short- and long-term consequences of playing football and the effect of heading on brain structure and function have been debated in professional football,[1-8] but more specifically in youth players.[9-14] In detail, four systematic reviews on the effects of football heading found no overall effect for heading on adverse outcomes; the consequences of repetitive heading to be unclear and various methodological shortcomings limit the evidence for persistent effects on brain structure/function.[3,4,6,8] The consensus statement of the head injury summit described that acute or chronic neurocognitive effects from heading are elusive, also due to different research methodologies.[5] Other research on retired football players and heading may suggest that changes are reversible or that heading may not be as harmful as commonly thought.[2] Regarding youth soccer, a review on heading in adolescent and children as a potentially dangerous play concluded that there is no evidence that heading in youth soccer causes any permanent brain injury and there is limited evidence that heading may cause concussion.[11] In addition, the large analysis of longitudinal surveillance data from US high schools found that heading is the most common activity associated with concussions, but the most frequent mechanism was athlete-to-athlete contact.[10]

Uncertainty around heading within the football community developed due to studies that described structural and functional white matter abnormalities and neurocognitive impairment in relation to heading and repetitive "sub-concussive" blows.[15-17] For instance, a recently published study let players perform 20 headers in 10 minutes to simulate the heading incidence in young adult players to investigate the acute effects of heading.[18] Currently, it is unclear whether heading effects players' brain anatomy and physiology. Therefore, the scientific debate continues about a potential header-induced brain damage for elite and amateur football players. In this context, the football federation of the United States (US Soccer) in 2015 decided to prohibit any kind of heading in children up to the age of 10 years and limited heading in training for the ages 11-13 years.[19] Two empirical reviews on the implementation and adherence to this US Soccer heading guidelines and purposeful heading in youth soccer have previously been published and reported low number of headers and concussions.[20,21]

However, a more precise understanding of the heading incidence, specifically in young players, is not only beneficial for such a debate, but would also facilitate an improved estimation of the potential effect of a header ban. In addition, it has to be taken into account that between-countries differences in rules, coaching approaches, and traditions may exist and affect the number of headers and mode of heading.

A more reasonable approach to assess the heading exposure in youth football was recently conducted by Sandmo et al.[14] They quantified heading exposure in an international youth football tournament with no heading restrictions by observing the number of heading including players from both sexes with similar ages compared to the present study.

As the methodological approaches of assessing heading data vary thereby rendering comparisons difficult, the present study aimed at serving as normative data for other studies concerning heading exposure in children's and youth' football. Therefore, the primary aim of this study was to analyze the magnitude of the heading incidence in children's and youth' football across Europe by use of video recordings. In detail, we examined (i) the match and training number of headers and (ii) the types of headers in children's and youth' football in eight European countries.

2 | MATERIALS AND METHODS

The study design, methods, and protocols were in accordance with the Declaration of Helsinki and approved by the Human Research Ethics Committee of the Saarland University (identification number: 21/17) as well as by the regional or local ethics committees of the universities in Denmark, England, Greece, Italy, Romania, Spain, and the Netherlands. The study was registered at clinicaltrials.gov (NCT03868553).

2.1 | Design

In a cross-sectional observational design, one match from each of 480 different teams was recorded in eight European countries (60 teams per country) via video during the second half of the regular season 2017/18 (March-July 2018) and the first half of the regular season 2018/19 (July-November 2018). One training session of 312 of these 480 teams was recorded additionally.

2.2 | Participants and inclusion criteria

Clubs with Under-10, Under-12 (both of them female, male, or mixed) and male and female Under-16 teams were eligible to participate and were contacted by the national research teams with the explicit intention to recruit a sample as representative as possible for the distribution of teams across playing levels in all participating countries. Teams were approached via personal contacts to team officials and coaches, general invitations to different teams and via the help of local football associations. Formal inclusion criteria for participating teams were as follows: (1) officially registered in the football association; (2) regular training; (3) regular participation in official matches. The overall distribution of playing levels (corresponding to age-dependent ranking in each country) was as follows: 17% highest leagues, 36% average leagues, and 47% lowest leagues. Written and verbal informed consent was obtained from each participating team. In case of a head injury, written consent was obtained from players and their parents.

2.3 | Heading measures

Standardized heading protocols were developed to guarantee an equal assessment of headers in each participating country. Heading characteristics were analyzed with regard to defined criteria; accordingly, the following characteristics were captured from video recording:

- Header types: single intentional headers; unintentional headers by getting hit; header duels; other (eg, head contacts with the ball during tackles).
- Match situations: free game play; corner kick; throw-in; free-kick/goal kick.
- Position of the player: goalkeeper; defender; midfielder; striker.
- Flight course of the ball: <5 meters; 5-10 meters; 10-20 meters; >20 meters.
- Point of contact on the players' head: frontal; parietal; occipital; temporal, face.

2.4 | Injury and match exposure

In case of a head injury, the concerned player and her/his parents were contacted to receive follow-up information. Detailed information on the injury was recorded using a standardized injury registration form, which has been adapted to injury registration forms that have been previously used to gather injury information in football players.[22,23] Match and training exposure was calculated as follows[24]:

$$\text{number of matches or training sessions} \times \text{number of players on the field} \times \text{duration of the match or training session in hours.}$$

2.5 | Inter-rater reliability

Five matches from each country cohort (total 40 matches with 80 teams) were screened by a researcher from the main research team (FB) to check for inter-rater reliability. Reliability was based on total headers and is presented as percent of agreement. These matches were randomly chosen and included two matches of Under-10, two matches Under-12, and one match Under-16. The comparison for inter-rater reliability of total headers revealed a percent agreement of 100% in 40 (50%), 90%-99% in 15 (19%), and <90% in 25 (31%) teams.

2.6 | Statistical analyses

All statistical analyses were performed using Microsoft Excel 2019 and SPSS 25 (IBM Statistics). Heading frequencies are presented as total numbers, headers per match and team (mean and standard deviation), median, minimum and maximum, and as incidence rates (IR) per 1000 match/training hours. IRs for headers and head injuries were calculated using formulas that have been previously used[25]:

$$\text{Incidence} = (\text{number of injuries or headers/hours of match/training exposure}) \times 1000$$

$$\text{Lower95\%CI} = \text{Incidence}/\text{e}1.96 \times (\text{square root } [1/\text{number of incidents}])$$

$$\text{Upper95\%CI} = \text{Incidence} * \text{e}1.96 \times (\text{square root}[1/\text{number of incidents}]).$$

Comparisons between incidence rates of Under-10, Under-12, and Under-16 male and female are presented as incidence rate ratios (IRR).

For match play, the raw heading data were checked for homogeneity of variances by Levene and Brown-Forsythe tests. In case of violation of homogeneity of variances (age group comparisons), Welsch's correction for F in one-way ANOVA (factor: group) was used. For post hoc comparisons, the Games-Howell test was employed. The same statistical procedure was used for comparisons between countries in Under-10 and Under-16 females. When variances were homogenous (Under-12 and Under-16 males), one-way ANOVA (factor: group) and Scheffé (post hoc) was used to detect differences. For training data, one-way ANOVA (factor: group) was used and for post hoc comparisons, the Scheffé test was employed.

3 | RESULTS

3.1 | Heading in match play

In total, one match was recorded from 480 teams throughout the eight countries corresponding to a total match exposure of 4,302.4 hours. Match exposure, recorded matches, and total headers for the three age groups are displayed in Table 1 and Figure 1. The proportion of full male teams in Under-10 and Under-12 age groups was 75%, mixed teams 23%, and full female teams 2%.

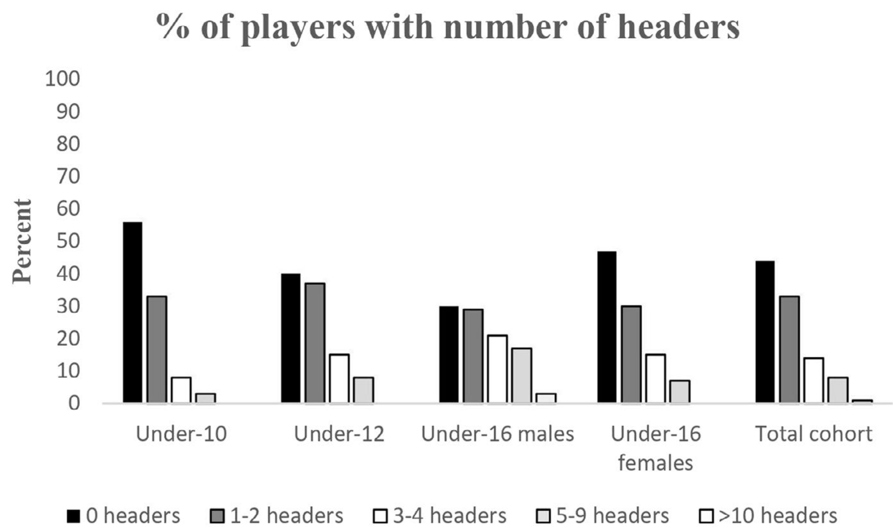
TABLE 1 Match exposure, number of recorded matches, total headers (IR/1000 match hours; mean ± SD), and head injuries (IR/1000 match hours)

	Under-10	Under-12	Under-16 males	Under-16 females	Total cohort
Number of teams (with 1 recorded match)	160	160	86	74	480
Match exposure [h]	839.6	1415.1	1146.5	901.2	4302.4
Total headers (n)	1408	2940	3055	1310	8713
Headers per match	8.8 ± 6.7	18.4 ± 10.6	35.5 ± 15.6	17.7 ± 9.5	18.2 ± 13.9
Median	7	17	36	17	15
Range (min-max)	0-35	0-48	6-73	2-42	0-73
Heading IR	1677	2078	2665	1454	2025
95% CI	1592-1767	2004-2154	2572-2761	1377-1535	1983-2068
Headers per player	0.9 ± 1.4	1.6 ± 1.9	2.6 ± 2.8	1.4 ± 2.1	1.6 ± 2.1
Median	0	1	2	1	1
Head injuries (n)	1	1	0	1	3
Head injury IR	1.19	0.71		1.11	0.70
95% CI	0.17-8.46	0.10-5.02		0.16-7.88	0.23-2.16

Note: Headers per match and team/player are mean and standard deviation.

Abbreviations: CI, confidence interval; h, hours; IR, incidence rate.

FIGURE 1 Percent of players with number of headers



3.2 | Heading difference between age groups

Heading differences between age groups in match play are shown in Table 2 as incidence rate ratios (IRR). The heading incidence in Under-10 players was lower (−19%) compared to Under-12 and Under-16 males (−37%), respectively. Under-16 females had a lower heading incidence compared to Under-10 (−13%), Under-12 (−30%), and Under-16 males (−45%). Under-12 had a lower heading incidence compared to Under-16 males by −22%.

When considering the raw heading data regardless of exposure times (headers per match), comparisons between Under-10 and Under-16 females showed a different direction. Headers per match were lower in Under-10 compared to Under-16 females. Total headers between age groups differed significantly (F (1, 3) = 98.79, $P < .01$). All cross-comparisons of age groups showed significant post hoc results ($P < .001$), except for the comparison of Under-12 and Under-16 females ($P = .96$).

3.3 | Heading differences across European countries

Total headers varied between countries in all age groups (Table 3). Headers per team and match for a given country

TABLE 2 Heading difference between age groups in match play and training sessions

	Under-10	Under-12	Under-16 female	Under-16 male
Under-10	_	MP 0.81 (0.76-0.86) TS 0.93 (0.88-0.98)	MP 1.15 (1.07-1.24) TS 1.98 (1.85-2.12)	MP 0.63 (0.59-0.67) TS 1.85 (1.74-1.96)
Under-12	MP 1.24 (1.16-1.32) TS 1.08 (1.02-1.14)	_	MP 1.43 (1.34-1.53) TS 2.14 (2.01-2.28)	MP 0.78 (0.74-0.82) TS 1.99 (1.89-2.10)
Under-16 female	MP 0.87 (0.80-0.94) TS 0.51 (0.47-0.54)	MP 0.70 (0.66-0.75) TS 0.47 (0.44-0.50)	_	MP 0.55 (0.51-0.58) TS 0.93 (0.87-1.00)
Under-16 male	MP 1.59 (1.49-1.69) TS 0.54 (0.51-0.58)	MP 1.28 (1.22-1.35) TS 0.50 (0.48-0.53)	MP 1.83 (1.72-1.96) TS 1.07 (1.00-1.15)	_

Note: Numbers are incidence rate ratios with 95% confidence intervals in parentheses.

Abbreviations: MP, match play; TS, training sessions.

ranged between 2.9 and 15.2 in Under-10, 10.4 and 27.4 in Under-12, 11.6 and 23.6 in Under 16 females, and between 23.5 and 51.0 in Under-16 males. Only, the difference between countries in Under-10 was significant (F (1, 7) = 13.10, $P < .001$).

3.4 | Header types and characteristics

The overall proportions of the four different header types, set plays and match situations, flight course, and point of contact on the players' head are shown in Figure 2. The same trend is apparent for each age group. The most frequent header type was single intentional headers (80%). The predominant match situation for the total cohort that involved headers were free game play (65%) and throw-ins (21%). Expectedly, goalkeepers accounted for the smallest proportion of headers being performed (<1%) with defenders (44%) and midfielders (40%) showing almost an equal proportion. The flight distance of the ball for the total cohort when players headed the ball was most frequently <5 m (42%). The point of contact on the players' head during headers in all age groups was predominantly the frontal part of the head (71%).

3.5 | Heading in training

In total, one training session was recorded in 312 teams corresponding to a total training exposure of 2,634.4 hours. Training exposure, recorded training sessions, and total headers for the three age groups are displayed in Table 4.

3.6 | Heading difference between age groups

Heading differences between age groups in training sessions are shown in Table 2. The heading exposure, expressed as IRRs, was lower in Under-16 males compared to Under-10 and Under-12 (by −46% and −50%, respectively). Under-16 females had a lower incidence compared to Under-10 and Under-12 (−49% and −53%, respectively). The difference between Under-16 females compared to Under-16 males was merely −7%.

With respect to the raw heading data independent of exposure times (headers per training), Under-16 males headed more often compared to the other age groups. Under-16 females had lower numbers compared to Under-12 and Under-16 males. Total headers between age groups did not differ significantly (F (1, 3) = 0.86, $P = .46$).

3.7 | Header types and characteristics

The overall proportion of the different header types were 96% single intentional headers, 2% header duels, 1% getting hit by a ball, and 1% others. For set plays and match situations, the overall proportion were 83% free game play, 14% throw-ins, 2% corner kicks, and 1% free kicks. The proportion for flight distance was 80% <5 m, followed by 14% between 5-10 m, 4% between 10-20 m, and 2% >20 m. The contact on the players' head was 87% the frontal part, 11% parietal, 1% temporal, and <1% occipital and face each.

3.8 | Head injuries in match play and training sessions

Three head injuries (head contusion, concussion, and unknown diagnosis) occurred corresponding to an IR of 0.70 (95% CI, 0.23-2.16) per 1000 match hours. One player with a concussion (Under-16 female) had a time loss of 14 days. The injury mechanism was a collision with the goalpost when falling to the ground. A head contusion (Under-12) and an unknown head injury (Under-10) did not lead to time loss. The mechanisms were collisions with the opponents. None of the head injuries was heading-related. No head injury occurred during all training sessions.

TABLE 3 Total headers (IR/1000 match hours; mean ± SD) in eight European countries

	Denmark	England	Germany	Greece	Italy	Romania	Spain	The Netherlands
Under-10								
Headers per match	2.9 ± 2.5	8.5 ± 4.9	15.2 ± 8.1	10.5 ± 5.5	8.5 ± 4.9	13.2 ± 7.4	6.5 ± 5.2	5.3 ± 5.0
Incidence rate	1436	1420	2608	1373	2322	2106	1372	891
95% CI	[1110-1857]	[1222-1652]	[2330-2918]	[1199-1571]	[1958-2698]	[1866-2377]	[1155-1631]	[737-1078]
Under-12								
Headers per match	10.4 ± 7.2	20.8 ± 8.2	24.0 ± 8.9	19.9 ± 8.8	15.4 ± 7.3	22.0 ± 10.7	27.4 ± 10.8	9.3 ± 6.9
Incidence rate	1516	2778	2661	2161	1730	2444	2491	916
95% CI	[1323-1737]	[2523-3058]	[2433-2910]	[1959-2384]	[1535-1950]	[2226-2684]	[2291-2709]	[793-1058]
Under-16 male								
Headers per match	30.8 ± 11.3	51.0 ± 9.8	38.8 ± 13.0	23.5 ± 10.3	27.8 ± 13.8	39.2 ± 13.6	50.9 ± 16.1	26.2 ± 10.4
Incidence rate	2234	4352	3025	1945	2214	2680	3479	1791
95% CI	[2017-2473]	[3990-4746]	[2739-3342]	[1712-2211]	[2005-2446]	[2427-2958]	[3190-3795]	[1587-2021]
Under-16 female								
Headers per match	11.1 ± 2.2	23.6 ± 6.4	18.7 ± 13.8	21.4 ± 5.4	13.7 ± 5.5	14.4 ± 12.6	22.4 ± 8.0	13.4 ± 8.3
Incidence rate	983	1965	1768	1522	1329	1600	1531	1188
95% CI	[799-1210]	[1730-2233]	[1532-2041]	[1331-1740]	[1070-1650]	[1359-1884]	[1343-1745]	[991-1424]

Note: Headers per match and team are mean and standard deviation. No throw-ins allowed in the Dutch teams Under-10 and Under-12.

Abbreviations: CI, confidence interval; IR, incidence rate.

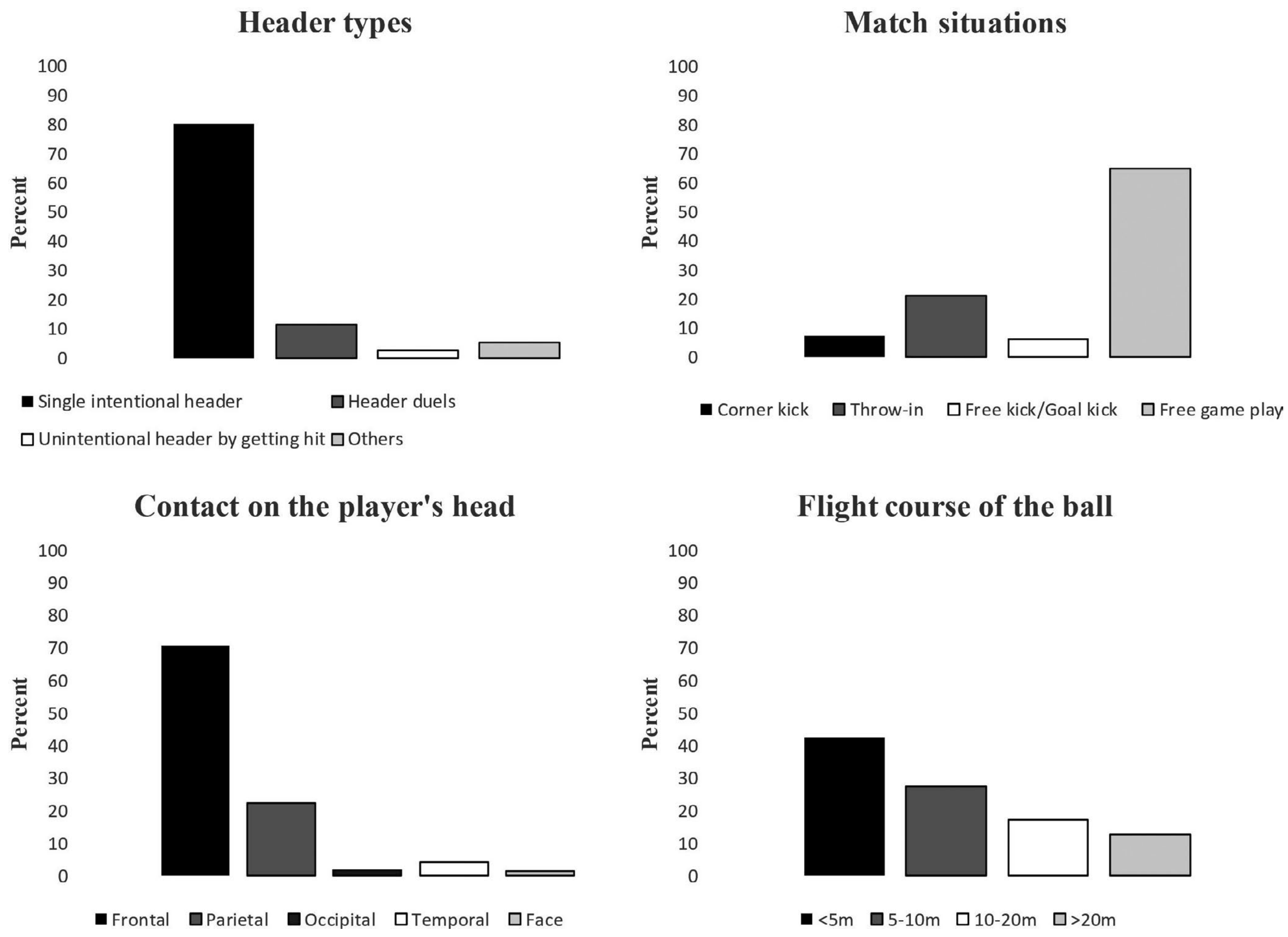


FIGURE 2 Header types, set plays and match situations, flight course, and point of contact on the players' head

TABLE 4 Training exposure, number of recorded training sessions, total headers (IR/1000 match hours; mean ± SD), and head injuries (IR/1000 match hours)

	Under-10	Under-12	Under-16 males	Under-16 females	Total cohort
Number of teams (with 1 recorded training session)	109	106	44	53	312
Training exposure [h]	455.1	714.6	923.0	581.7	2634.4
Total headers (n)	2109	3578	2318	1362	9367
Headers per training session	21.3 ± 87.0	35.8 ± 86.8	45.0 ± 15.6	34.1 ± 126.9	32.3 ± 92.5
Median	4	6	13	4	6
Range (min-max)	0-824	0-600	0-862	0-284	0-862
Heading IR	4634	5007	2511	2341	3556
95% CI	4441-4836	4846-5174	2411-2616	2220-2469	3484-3628
Head injuries (n)	0	0	0	0	0

Note: Headers per training session and team are mean and standard deviation.

Abbreviations: CI, confidence interval; h, hours; IR, incidence rate.

4 | DISCUSSION

The purpose of this UEFA Heading Study was to examine the characteristics of heading in children's and youth' football (soccer) in eight European countries. The current data present the first real-life assessment of the heading incidence during match play and training in a large-scale Europe-wide sample of young football players. The main findings were as follows: (1) The lowest number of headers per match was observed in Under-10 teams, followed by Under-16 female and Under-12 teams, whereas Under-16 male teams experienced the highest heading exposures. (2) Taking exposure time into account, the lowest incidence of heading was observed in Under-16 females. (3) Considerable differences between countries were apparent. (4) Very few head injuries (none of them heading-related) resulted in a low incidence rate. (5) Under-10 teams carried out the lowest number of headers per training session, followed by Under-16 females, Under-12, and Under-16 males. (6) In contrast, when taking exposure times into consideration, lower heading incidence rates were found in Under-16 females and males compared to Under-10 and Under-12. (7) No head injury occurred during all training sessions.

The recent attention of head injury management in football was driven by the fear that repeated traumatic brain injuries (eg, concussions) and repetitive head impacts may have the potential to increase the potential for the development of chronic traumatic encephalopathy (CTE), a condition characterized by neuropsychiatric symptoms.[26] Interest in youth football is a consequence of several studies addressing the potential effect of repetitive heading ("sub-concussive blows") on brain function in children and adolescents in this context.[4,6] This may be especially relevant in younger ages (<12 years) where repetitive head impact exposure may be seen as a risk factor for CTE and may reduce resilience to late life neuropathology.[27] To date, it remains unknown whether intentional heading in football represents a form of repetitive minor injury[1] and as such a cause-and-effect relationship between headers and possible late brain damage remains hypothetical. The term "sub-concussive" describes a cranial impact with potential neuronal changes similar to those in concussion, but without the symptoms of a concussion.[28] One in this discussion is the lack of large-scale longitudinal data and studies with high external validity and accurate heading incidence in youth' football, respectively. Determining the heading incidence appropriately requires standardized and prospective recording with detailed header characteristics in order to draw conclusions and present more in-depth data. Such information would help to identify whether there are long-term effects of repetitive heading or not. This lack of available knowledge is illustrated by mechanistic studies that use scenarios without proper external validity.[29-31] For instance, recently published research used a high number of headers in a short period of time (20 headers in 10 minutes) in an attempt to simulate a ecologically valid heading incidence.[18] However, the present findings do not support such large numbers of headers by a single player as supported by the low number of headers in young players and the high proportion of players that performed zero (44%) and 1-2 headers (33%), respectively. Therefore, results from such studies should be interpreted with caution.

Before examining relationships between heading and potential sequelae, (descriptive) studies should define the problem more closely and focus on the heading incidence in a realistic setting such as matches and/or training. Over the years, some studies have attempted to record the number of headers in adolescent's football. The methodological approach varied among these studies thereby rendering comparisons difficult. Some researchers drew conclusions based on self-reported estimates of heading in matches and training sessions[32-34] and used online surveys such as the US Soccer Online Concussion and Heading Surveys.[20,21] Other studies monitored heading incidents by counting the number of times that each participant headed the ball,[14,17,35-39] or used a device that measured acceleration of head impacts.[40-45] However, those studies that monitored exact heading incidents in matches revealed partly different results from the present ones. Our study showed the lowest heading exposure per match and team in Under-10, followed by Under-16 females, and Under-12. Under-16 males showed the highest number of headers. These heading exposures are higher than those reported in some of the aforementioned studies.[35,38,43] Reasons for these differences may be the low number of players and matches evaluated in previous studies as well as different methods of observing (parents, trained observer, sensors) heading. In contrast, two of the observational studies approximately match the present findings regarding the number of headers per match and team.[37,39] Two reports do not present exact data of total headers per match and team,[41,46] whereas one report with older adolescents and young adults matches the number of headers in the present Under-16 male teams.[36] The recently published study by Sandmo et al quantified heading exposure in an international youth football cup with almost 30 000 players ranging from 10 to 19 years, which is very similar to the present study regarding age groups.[14] They could demonstrate large variations in head impact exposure with age and sex as significant influencing factors. The same trend was observed in the present study, where older age groups had higher heading exposures. Additionally, the high number of players that had 0 headers or headed only 1-2 times in this study matches the results of Sandmo et al.[14] However, comparisons between Under-12 and Under-16 males revealed higher number of headers per match and team in the present study (approx. 4 times higher in Under-12 and 1.6 times higher in Under-16 males), whereas Under-16 females had same numbers.

When taking exposure time into consideration, the heading incidence rate was the lowest in Under-16 females indicating that female players do not use the head to play the ball as often as their male counterparts (neither in match play nor in training sessions) or that the playing style differs between genders. Definitive reasons for this difference have yet to be elucidated.

Those studies that specifically recorded headers in training are rare to date.[17,42] The number of headers per training session in the present study was lower when compared to one of the aforementioned studies that showed heading frequencies in training[17] and higher when compared to another.[42] However, the authors of these two studies included a low number of training sessions and an adolescent player sample compared to our study. This may predispose these earlier studies to a small sample bias. Somewhat surprisingly, lower heading exposure (in regards to IR) in training was found by Under-16 males and females compared to Under-10 and Under-12. This may reflect the coaches´ attitude that the age range between 9 and 12 is most appropriate for learning (and, thus, training) headers. Consequently, the number of headers in training appears to decrease with increasing age. The upper range of heading during training sessions goes far beyond match play in all age groups. The overall reduction of headers in match play compared to training sessions is −43% (IRR 0.57). This may indicate that there is room for a reduction of headers in youth football's developmental strategies for training headers.

A large variability of headers in match play was apparent between countries, thereby possibly forming national "patterns" around heading (still to be defined). However, only the Under-10 age group reached significance in the difference in heading numbers between countries. It appears that in some European countries heading is more dominant in match play than in others. Reasons for this variability may be differences in training curricula, exemptions from current rules (eg, no throw-ins in the Netherlands for children), personal attitudes of coaches, or even cultural differences in football match play. These reasons may eventually be more present in the younger age groups. Nevertheless, as this is the first large-scale study in this area, it remains unknown if the present numbers represent rather low or high heading exposures as compared to other regions of the world (eg, the United States of America where a header ban during match play is in place up to the age of 10).

It has previously been shown in adults' football that heading duels are particularly key in the occurrence of head injury.[47-49] Therefore, header duels and unintentionally getting hit by a ball can be considered to be more likely accompanied by (head injury) consequences.[50,51] It is tempting to assume that the contact force between the ball and the player's head is an important consideration for head injury risk.[1,11,50,51] Therefore, it raises the question if long-distance shots that fly at higher velocities than short-distance shots, could lead to greater contact force on the head.[5,14] Results from a biomechanical study found that goal kicks and punts, which are usually long-distance shots, resulted in higher linear and rotational head accelerations.[52] Most headers for the total cohort occurred after short-distance shots of less than 5 m and only few were the result of shots from over 20 m. Additionally, the location of contacts on the players' heads is important because temporal, occipital, or parietal contact on the head may be a sign of unwanted and/or unaware contact with the ball. Such scenarios likely limit the preparedness of players for the incoming ball contact. A recently published study found shots and unintentional deflections to result in higher mean linear accelerations than purposeful headers.[53] Head impact location such as parietal part appears to result in larger rotational velocities of the head.[43] Frontal contact with the head usually reflects an active sequence allowing the player's body to prepare for the impact (eg, trunk and neck muscle activation).[1,50] In summary, most of the headers in our study appear to be of less (acute) potentially problematic characteristics. This would suggest that a large number of headers are intentional single headers and frontal contact with the head indicating a proper technique.

The ban by US Soccer in 2015 for players under the age of 10 years[19] due to concerns about heading and concussions has caused considerable attention. It was underpinned by some severe head injuries in professional football due to head-to-head contacts. However, as long as no imminent threat has been documented, banning fundamental parts of the worldwide distributed football game should always be the result of evidence-based decision making. A recent 9-year analysis of head injuries in high schools revealed a high number of concussions, though due to athlete-athlete contact rather than heading the ball.[10] The US Soccer Online Concussion Survey found that concussion rates were low and fewer than 1 in 5 concussions occurred during attempted purposeful heading of the ball.[21] Data on heading as a potentially dangerous play and the risk of concussion and persistent effects of heading was previously considered to be inconsistent and inconclusive.[8,10,11] Recent studies on (head) injuries in children's and youth' football found a low IR of head injuries,[22,23,54,55] matching the results of the present investigation. Studies specifically focusing on head injuries in children's and youth' football are, however, scarce and do hardly exist in sufficient number. Additionally, it is unknown whether and how this ban may have affected playing and coaching styles in Europe. It is beyond the scope of the present study to elucidate the effects of heading on long-term brain health or the relationship between repetitive head impacts and long-term sequelae, respectively. Therefore, the present study cannot elucidate the relevance of a possible heading ban in Europe for young players. It remains essential to investigate potential effects of such exposure to head impacts and a dose-response relationship of potential effects in future research.

5 | METHODOLOGICAL CONSIDERATIONS

Using a cross-sectional design, the present header characteristics only allow a "snapshot" of heading behavior in children's and youth' football. Therefore, it remains unknown whether the number of headers may typically change over the duration of a complete season. Nevertheless, including eight European countries, different age categories and teams with different league affiliations and league levels, respectively, strengthen the overall representativeness as shown by the large proportion of teams participating in lower and average leagues. The eight European countries were chosen to cover most of the European (cultural and geographical) regions and "football cultures." Additionally, as the US ban of heading was primary set for the age groups Under-10 and Under-12, one additional age group (Under-16 male and female) was added to cover the adolescent age for comparisons.

An analysis of differences between countries in training was deliberately omitted due to the different (partly low) number of training sessions that could be recorded in some countries. In contrast to the match observations within this study, the influence of a single country on the overall results therefore varied dependent on the number of training sessions recorded.

The analysis revealed a couple of outliers with very high numbers of headers during their training session, which is reflected in the large standard deviations of headers per training session and team. This was due to sessions that trained heading and may have been triggered by the project and the video analysis itself. Although we had advised coaches against this by conducting "normal" training sessions, it can therefore not be ruled out that participation in the "UEFA heading study" might have led some of them to give more emphasis to heading or the opposite, respectively.

The conducted video analyses can additionally be seen as a strength of this study as they offer the opportunity to exactly identify heading characteristics. The inter-rater reliability can be deemed sufficient. Nevertheless, in 31% of the teams the agreement was <90%. Reasons for disagreements during reliability control were video quality and camera angles. Unfortunately, measurements of ball velocities and contact forces on the head were not conducted.

6 | PERSPECTIVE

The present results represent novel data and add valuable information to the general discussion about the number of headers in children's and youth' football. Under-10 and Under-12 players had a low heading incidence in this database than older players. But importantly, the present results cannot provide clear information as to if a ban is necessary or not. It was not the scope of this study to investigate potential effects of such exposure to head impacts and a dose-response relationship of potential effects. When taking exposure times into account, it became evident that female players do not tend to perform as many headers as males. Differences between countries were apparent and may indicate a cultural and (possibly) a geographical/climate difference of header behavior across Europe. Surprisingly, the number of headers in training decreased with increasing age as Under-10 and Under-12 players had the highest heading incidence rates compared to Under-16 females and males, although the number of headers per training session was the lowest in the Under-10 age group. The present findings can serve as normative data for other studies concerning head impacts in children's and youth' football as being the first large-scale study in this area.

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COMPETING INTERESTS

TM is chairman (at the time of study conduction: deputy chairman). MV is member of UEFA's match operations, medical and antidoping unit.

ORCID

Florian Beaudouin https://orcid.org/0000-0003-0546-2979
Roberto Modena https://orcid.org/0000-0001-5194-5539

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