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Research article

Quantitative Analysis of Ball-Head Impact Exposure in Youth Soccer Players

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Abstract

Since the implementation of the US Soccer heading guidelines released in 2015, little to no research on ball-head impact exposure in the United States youth soccer population has been conducted. The purpose was to compare ball-head impact exposure across sex and age in youth soccer players over a weekend tournament. Ten male and female games for each age group (Under-12 [U12], U13, and U14) were video recorded at a weekend tournament for a total of 60 games. Ball-head impact exposure for each game was then coded following a review of each recording. Male players were 2.8 times more likely to have ball-head impacts than female players, ($p < 0.001$) particularly in the U14 age group when compared to the U12 age group ($p = 0.012$). Overall 92.4% of players experienced 0-1 ball-head impacts per game with the remaining players experiencing 2+ ball-head impacts per game. Ball-head impact exposure levels are low in the youth players. Most youth soccer players do not head the soccer ball during match play and those that did, only headed the ball on average once per game. Overall, the difference in ball-head impact exposure per player was less than 1 between all the groups, which may have no clinical meaning.

Key words: Repetitive head impacts, football, aerial challenges, concussion, heading.

Introduction

Repetitive head impacts (RHI), such as purposeful soccer heading, in youth and the short- and long-term effects of those impacts on overall physical and mental health pose significant public health concerns (Arbogast and McDonald, 2023). Much research has been conducted on RHI in recent years in sports such as American football, ice hockey, and soccer (Mihalik et al., 2012; Kontos et al., 2017; Caccese et al., 2023). Results from RHI research suggests that there may be short-term subtle changes in neuropsychological function, symptoms, and balance (Caccese et al., 2019; Levitch et al., 2020; Wilson et al., 2021). RHI is a cause for concern in soccer specifically because players purposefully use their heads to advance the ball in play, a skill called purposeful heading. Studies, mostly conducted in collegiate populations, suggest that those who headed the ball more often have worse neuropsychological function than those with lower heading exposure (Levitch et al., 2018, 2020; Caccese et al., 2019).

In 2015, in response to a class action lawsuit in California about the concern of RHI and potential for concussion, the United States Soccer Federation (US Soccer) implemented soccer heading guidelines developed by medical and coaching professionals (US Club Soccer, 2015; Strauss, 2015). These guidelines ban heading of a soccer ball in children 10 years and younger with children aged 11-13 years permitted to start practicing the skill of soccer heading, with recommendations to limit practice to 15-20 headers per week, with no restrictions to heading during match play (US Club Soccer, 2015). However, these cutoff points for heading were made by consensus by the US Soccer Sports Medicine Research Education and Advisory Panel and youth soccer representatives and were not evidence-based (Yang and Baugh, 2016). Currently, after the purposeful heading rule change, little to no research has been done on heading exposure and the effects of RHI in this population of youth soccer players in the US. The majority of research on RHI in the US has been done in the older populations beginning with interscholastic soccer athletes, aged 14-18 years old, and moving beyond (Covassin et al., 2003; Kaminski et al., 2007; Caccese et al., 2018).

In the time since US Soccer implemented the soccer heading guidelines, minimal research has been conducted in 11-13-year-old soccer players. Much of the research on ball-head impact exposure in youth focuses on either a weekend of games/tournament observing a handful of players (less than 20) or observing one sex and age group over one soccer season (Chrisman et al., 2016; Harriss et al., 2018; Beaudouin et al., 2020; Peek et al., 2021b). Youth players (14 years and younger) have been observed to only head the ball, on average, fewer than 3 times per game (Salinas et al., 2009; Chrisman et al., 2016; Harriss et al., 2018, 2019; Sandmo et al., 2020; Beaudouin et al., 2020). Heading exposure in the high school and collegiate populations has been tracked much more extensively with heading exposure increasing from on average 3 times per game at the high school level (Kaminski et al., 2007; Kaminski et al., 2008; Kaminski et al., 2020b; Kontos et al., 2011; McCuen et al., 2015) to 5 headers per game at the collegiate level (Kaminski et al., 2007; 2020b; McCuen et al., 2015; Press and Rowson, 2017; Reynolds et al., 2017). Very little research on heading exposure has been conducted at the professional level, however it has been reported that professional soccer players are exposed up to 20 headers per game (Matser et al., 1998; Cassoudesalle et al., 2020; Tierney and Higgins, 2021).

Sex, age, and event type are factors that affect ball-head impact exposure. Males are twice as likely to head the ball at all age levels than their female counterparts (Kontos et al., 2011; Reynolds et al., 2017; Kaminski et al., 2020b; Sandmo et al., 2020; Saunders et al., 2020). As

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mentioned above, ball-head impact exposure has also been reported to increase with age (McCuen et al., 2015; Reynolds et al., 2017; Harriss et al., 2019; Kaminski et al., 2020b; Sandmo et al., 2020; Peek et al., 2021a). The need to carefully monitor RHI in the 11-13 year old age group is paramount and warranted due to public perception of concussions and RHI versus a lack of information about this population (Schatz et al., 2020; Kim and Connaughton, 2021; Arbogast and McDonald, 2023). Therefore, the purpose of this study was to compare ball-head impact exposure across sex and age in youth soccer players during a weekend soccer tournament. We hypothesized that ball-head impact exposure would be greater in males compared to females and increase with age.

Methods

Ten male and ten female youth soccer games in each of the Under-12 (U12), Under-13 (U13), and Under-14 (U14) age groups were observed at a weekend tournament in the Midwest region of the United States. A total of 60 games were observed resulting in a sample size of 1674 players (828 females and 846 males) who participated in the sanctioned games observed by the research team. The 60 games that were observed were selected based on the tournament schedule allowing for the collection of 10 games in each age/sex group.

Ball-head impact exposure was captured through video recording with an AKASO Brave 6 action camera (AKASO, Frederick, MD). Video recordings were saved directly to an SD memory card for easy transfer to a computer for a detailed analysis and counting of the actual number of ball-head impacts.

The video camera was set up on the side of the soccer field to capture the soccer headers performed and any additional head impacts that occurred during the regulation soccer match. Similar to Patton et al., (2020) the video camera was set up near the midline with a third of the field in view, while the videographer moved the camera to follow the ball in play. The video recordings were then used to record the number of athletic-exposures with an athlete-exposure defined as one player participating in a game where they are exposed to the possibility of a purposeful header and/or other head impacts. Ball-head impacts were the only impacts that were counted. Other head impacts such as players' collisions, head to ground contact, etc. were not considered. Ball-head impacts were defined as any impact to the head that included the ball, even if it was unintentional. Due to the nature of video recording, obscured video may have reduced the accuracy of the ball-head impact count. To solve this issue, the video was watched frame by frame and a ball-head impact was counted if it seemed reasonable with the trajectory of the soccer ball.

One game from each group, for a total of 6 games, was watched by another member of the research team to check for inter-rater reliability. Reliability was based on total ball-head impacts for each game and was calculated using an intraclass correlation coefficient (ICC). The comparison revealed an ICC value of .985 indicating excellent reliability.

The ball-head impact data were analyzed using (1) an independent samples *t*-test to examine the effects of sex on ball-head impact exposure and (2) an analysis of variance (ANOVA) to determine the effects of age (U12, U13, U14) and the combined effects of sex and age on ball-head impact exposure per game in youth soccer players during the tournament. Cohen's *d* effect sizes were reported for significant findings to determine the standardized difference in the means. An *a priori* alpha level of .05 was set to represent statistical significance. The percentage of players who experienced 0, 1, 2, and 3+ ball-head impacts per game was also reported. All data were analyzed using the IBM Statistical Package for the Social Sciences Version 28 (SPSS, Armonk, NY).

Informed consent

This study was approved by the University of Delaware Institutional Review Board (UDIRB 1758775-1) and was determined to be exempt.

Results

A large percentage of players (76.9%) from each age group did not experience a ball-head impact during a game. The next largest category was those who had 1 ball-head impact per game, consisting of 15.5% of the youth players. There were 5.26% of players who had 2 ball-head impacts per game. Lastly, there were 2.4% of players in the 3+ ball-head impacts per game category. Figure 1 and Table 1 present the descriptive statistics of ball-head impact exposure per game based on sex and age.

Table 1. Ball-head impact exposure based on sex and age.

	Total Ball-Head Impacts	Total Players	Ball-Head Impacts per Player	Ball-Head Impacts per Game	95% CI	Range (min-max)
U12 Girls	30	240	0.13 ± 0.07	3.00 ± 1.70 †,#	1.78-4.22	1-6
U12 Boys	101	254	0.40 ± 0.16	10.10 ± 3.90 †,#	7.31-12.89	4-17
U13 Girls	54	300	0.18 ± 0.13	5.40 ± 4.20 †	2.4-8.4	2-16
U13 Boys	133	294	0.45 ± 0.24	13.30 ± 7.45 #	4.46-9.34	4-25
U14 Girls	69	288	0.24 ± 0.11	6.90 ± 3.41 †	4.46-9.34	3-12
U14 Boys	192	298	0.64 ± 0.24	19.20 ± 7.44 †	13.88-24.52	8-34
Females	153	828	0.18 ± 0.11	5.10 ± 3.56 §	3.83-6.37	1-16
Males	426	846	0.50 ± 0.24	14.20 ± 7.34 §	11.57-16.83	4-34
U12	131	494	0.26 ± 0.19	6.55 ± 4.67 *	4.36-8.74	1-17
U13	187	594	0.31 ± 0.23	9.35 ± 7.15	6.01-12.69	2-25
U14	261	586	0.44 ± 0.28	13.05 ± 8.46 *	9.09-17.01	3-34
Total	579	1674	0.34 ± 0.24	9.65 ± 7.33	7.76-11.54	1-34

Ball-Head Impacts per Game and Ball-Head Impacts per Player: mean ± standard deviation; CI=confidence interval; § Males > Females; * U14 > U12; † U14 boys > U12 girls, U12 boys, U13 girls, U14 girls; # U12 boys, U13 boys > U12 girls.

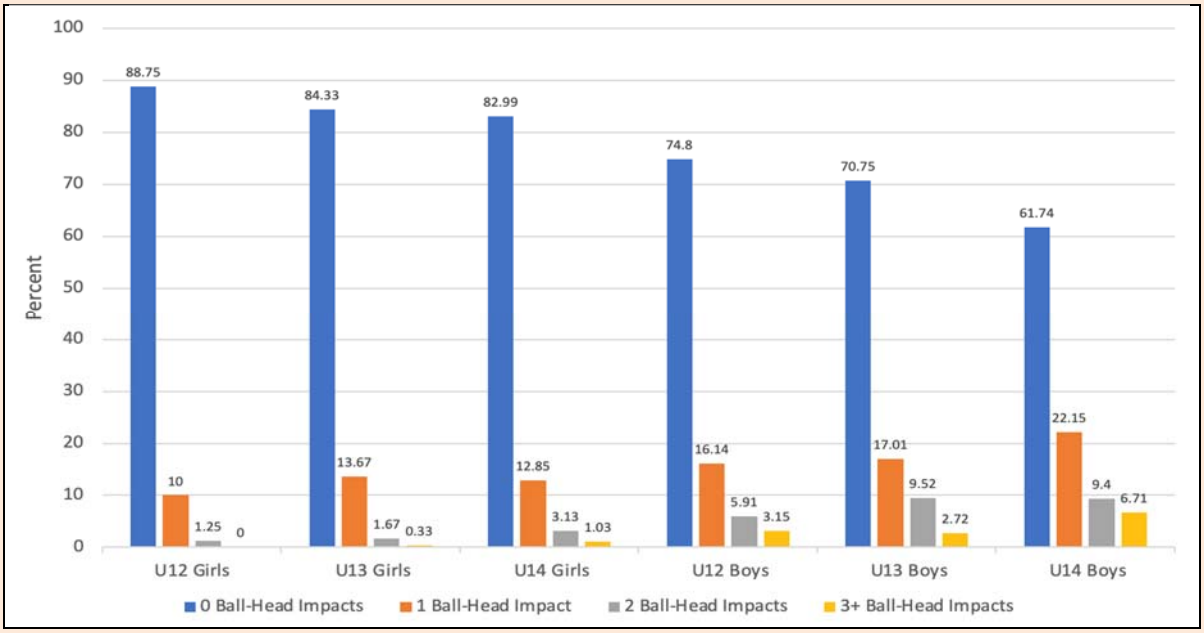

Figure 1. Percent of players with number of ball-head impacts.

Results from the independent samples *t*-test, with equal variances not assumed, revealed that males had significantly more ball-head impacts per game than females ($t = 6.114$, $df[41.91]$, $p < 0.001$, $d = 1.58$) (Table 1). The overall ANOVA for age showed a significant difference between the age groups ($F = 4.416$, $df[2,57]$, $p = 0.016$). The paragraph below with further break down the comparisons between the age groups. Preliminary comparisons for the ANOVA on the combined effects of sex and age revealed that the homogeneity assumption underlying an ANOVA was violated (Levene statistic = 3.609, $df[5, 54]$, $p = 0.007$). Therefore, the Welch statistic was used for the overall-test and the non-parametric Games-Howell adjustment for the post hoc comparisons. The Welch statistic showed a statistically significant difference between the male and female age groups with the males experiencing more ball-head impacts than the females (Welch statistic = 14.768, $df[5, 23.928]$, $p < 0.001$).

Post hoc analyses for age demonstrated that the U14 age group had significantly higher ball-head impact exposure than the U12 age group ($p = 0.012$, $d = 0.95$). Post hoc analyses for the combined effects of sex and age demonstrated that the U14 boys had significantly more ball-head impacts than the U12 girls ($p < .001$, $d = 3.00$), U12 boys ($p = 0.039$, $d = 1.53$), U13 girls ($p = 0.002$, $d = 2.29$), and U14 girls ($p = 0.004$, $d = 2.13$). Furthermore, the U12 boys and U13 boys had significantly more ball-head impacts than the U12 girls ($p = 0.002$, $d = 2.36$ and $p = 0.015$, $d = 1.91$, respectively). No other significant differences in ball-head impacts per game were exhibited. All means and standard deviations can be found in Table 1.

Discussion

In the time since US Soccer implemented their soccer heading guidelines, very few studies have examined heading exposure in the 11 - 13 year old age group in the United States (Chrisman et al., 2016, 2019; Kaminski et al., 2020a). This is the first study to examine ball-head impact exposure in a large population of male and female soccer players in the U12, U13, and U14 age groups. The majority of the soccer players (92.4%) only experienced 0 - 1 ball-head impact in a game. Overall, male players had more ball-head impacts per game than their female counterparts with the U14 boys having the most ball-head impacts. Ball-head impact exposure also increased with age as the U12 groups had less ball-head impacts than their counterparts in both the U13 and U14 groups.

In this study, 92.4% of the youth soccer players experienced 0-1 ball-head impact per game (Figure 1). The 0 ball-head impact per game category was the largest in each age group followed by the 1 ball-head impact per game category. Similar to our study, two European studies report that the majority of players only head the ball 0-2 times per game (Sandmo et al., 2020; Beaudouin et al., 2020). However, in both those studies, those who headed the ball 1 - 2 times per game represented a larger percentage of players than in the current study (approximately 30% vs. 15% of players); in other words, the current study had more players with zero headers compared to the previous studies with similar age groups. It is important to note that the United States, England, Scotland, and Northern Ireland are the only countries to have restrictions on heading exposure in youth soccer players. It is possible that the heading restrictions in practice have an effect on game heading exposure; therefore, caution must be used when comparing to studies done in countries with no heading restrictions. The US Soccer heading guidelines may affect the heading behaviors in the 11 - 13-year-old soccer players leading to a higher percentage of players not heading the ball. For example, because players are still learning to head the ball, they may not feel comfortable doing so in a game setting yet or there may be greater awareness about the potential risks of heading causing parents not to want their child to head the ball or athletes choosing not to. The Get aHEAD Safely in Soccer program recommends using

lightweight soccer balls for practicing heading so that players can train in a lower-risk setting; lighter balls result in lower head acceleration (Peek et al., 2021c; Caccese and Kaminski, 2016; Wahlquist and Kaminski, 2021). This is an example of how coaches for youth athletes might be able to incorporate safe and effective heading drills, especially with youth players who are reluctant to head the regulation soccer balls (larger size and mass than the lightweight balls).

The difference in heading exposure between males and females is evident in all levels of play, starting with the youth up through the professional levels (Kontos et al., 2011; Chrisman et al., 2019; Kaminski et al., 2020b; Nelson et al., 2020; Sandmo et al., 2020; Saunders et al., 2020; Huber et al., 2021). An exception to this is a study by Peek et al. (2021b) where the U17 females had a higher heading incidence rate compared to other male age groups. In our youth cohort, the males headed the ball 2.8 times more than the females (14.2 vs. 5.1 headers per game), a fact that is consistent with other literature (Kontos et al., 2011; Kaminski et al., 2020b; Nelson et al., 2020; Sandmo et al., 2020; Saunders et al., 2020; Huber et al., 2021). In a recent studies involving cohorts aged 11 years to the professional level, males were reported to head the ball 1.3-2.7 times more than their female counterparts (Kontos et al., 2011; Kaminski et al., 2020b; Nelson et al., 2020; Sandmo et al., 2020; Saunders et al., 2020; Huber et al., 2021). We speculate that males may have a more aggressive style of play compared to their female counterparts; therefore, we propose that males may be more likely to be presented with more opportunities to head the ball. Another possible explanation for the heading exposure differences could be the training regimen. Males and females may focus on developing different skill sets to be used in games whereas males maybe incorporate more purposeful heading versus females who maybe incorporate more tactical skills.

An increase in ball-head impact exposure with increasing age was observed in this study. The U12 girls' teams in our study had about 90% of players who had no ball-head impact during a game while the U14 boys' teams had about 60% of players without any ball-head impacts in a game. Previous literature supports the notion of an increase in heading exposure as age increases (Chrisman et al., 2019; Harriss et al., 2019; Sandmo et al., 2020; Beaudouin et al., 2020). Beaudouin et al. (2020) observed a difference in heading exposure in their groups of U10, U12, and U16 soccer players. The youngest group started at 9 headers per game as a team which increased to 36 headers per game for the oldest group (Beaudouin et al., 2020). In a recent study by Sandmo et al., (2020) games from the U12 age group up through the professional level were observed with a reported increase in heading exposure with age (1.2 to 3.4 headers/player/hr for the boys and 0.6 to 2.7 headers/player/hr for the girls), even when looking just at the U12, U13, and U14 age groups (Sandmo et al., 2020). However, one needs to be careful when comparing these two studies as one is in units of headers per game and the other is headers per player. It is possible that the increase in headers with age could be due to more players heading the ball, some players heading the ball more often, or it is likely both (Sandmo et al., 2020; Beaudouin et al., 2020). Two research groups that studied the high school and collegiate populations reported that collegiate soccer players head the ball more than the high school players (McCuen et al., 2015; Kaminski et al., 2020b). The two most recent studies involving professional level players reported a wide range of heading exposure from 49 (Cassoudesalle et al., 2020) to 107 (Tierney and Higgins, 2021) total headers per game as a team in this population. As players age, we argue that they refine and improve their technique and ability to head the ball while learning tactics to protect themselves during aerial challenges.

There are some limitations to the current study. First, the video cameras used were not of professional quality and the users were not professional videographers. As a result, some of the video quality was not perfectly clear and it is possible that ball-head impacts may have been out of view or other players obscured the view of a ball-head impact. Secondly, the population observed only represents the Midwest region of the United States, therefore we do not know if other regions would have similar ball-head impact exposure rates. Ball-head impact exposure only included games and not practices. Research has shown that there are differences in ball-head impact exposure in games versus practices with higher rates typically in games (Reynolds et al., 2017; Kaminski et al., 2020b). No kinematics or kinetics of head impacts were recorded. There is also no possible way of knowing why or why not players choose to head the ball.

Conclusion

This was the first study since the implementation of the US Soccer heading guidelines to examine ball-head impact exposure in the three age groups (U12 - 14) who have all begun to practice heading. Ball-head impact exposure levels are still quite low and may not be clinically meaningful as the majority of players experienced 1 ball-head impact or less per game. Males were observed to have significantly more ball-head impacts than females in games during a tournament. Ball-head impact exposure also increased with age in both the males and females. The low levels of ball-head impact exposure may be a positive outcome in the youth since subtle changes have been previously observed in neuropsychological function, symptoms, and balance related to RHI exposure, especially in adult populations.

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Key points

- Ball-head impact exposure in youth soccer players was compared across sex and age during a weekend soccer tournament.
- Youth soccer players experienced low levels of ball-head impact exposure with the majority of players experiencing 0-1 ball-head impacts per game.
- Ball-head impact exposure was higher in males versus females and also increased with age.

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