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CLINICAL FEATURE
REVIEW

Is Heading in Youth Soccer Dangerous Play?

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ABSTRACT

Background: Soccer is among the most popular youth sports with over 3 million youth players registered in the U.S. Soccer is unique in that players intentionally use their head to strike the ball, leading to concerns that heading could cause acute or chronic brain injury, especially in the immature brains of children.

Methods: Pub Med search without date restriction was conducted in November 2014 and August 2015 using the terms soccer and concussion, heading and concussion, and youth soccer and concussion. 310 articles were identified and reviewed for applicable content specifically relating to youth athletes, heading, and/or acute or chronic brain injury from soccer.

Results: Soccer is a low-risk sport for catastrophic head injury, but concussions are relatively common and heading often plays a role. At all levels of play, concussions are more likely to occur in the act of heading than with other facets of the game. While concussion from heading the ball without other contact to the head appears rare in adult players, some data suggests children are more susceptible to concussion from heading primarily in game situations. Contributing factors include biomechanical forces, less developed technique, and the immature brain's susceptibility to injury.

Conclusions: There is no evidence that heading in youth soccer causes any permanent brain injury and there is limited evidence that heading in youth soccer can cause concussion. A reasonable approach based on U.S. Youth Soccer recommendations is to teach heading after age 10 in controlled settings, and heading in games should be delayed until skill acquisition and physical maturity allow the youth player to head correctly with confidence.

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Introduction

Soccer is the most popular sport in the world with estimates of 250 million players playing in over 200 countries.[1] US youth soccer in 2014 reported 3055,148 registered players, with the most recent gender breakdown in 2008 reporting 52% boys and 48% girls.[2]

Soccer is also unique in that it is the only sport where a player uses their head to intentionally strike the ball during the course of play. This raises concerns that heading might result in acute or chronic brain injury. Researchers have reached variable conclusions regarding the risk of brain injuries from heading the ball. Most of the research has been conducted in adult players. Early studies reported evidence of chronic brain dysfunction in professional players. However, confounding risk factors, including behavior off the field and concussions not related to ball contact, make it difficult to implicate heading in those findings.[3,4] Subsequent studies that tried to control for some of these variables for the most part did not conclude that heading is a risk factor for acute or chronic brain injury.[5,6]

Recent studies using more sensitive measures of acute brain dysfunction and also more sensitive brain imaging techniques have re-raised concerns that heading may cause injury particularly above certain thresholds.[7,8] Few studies have examined head injury in youth soccer. Generally, it appears that concussions most often occur in the act of heading, but player-to-player contact is the most frequently cited cause of this injury.[9,10]

This article will review the limited research in youth soccer related to heading, pertinent literature in adults that examines heading with regards to acute and chronic brain injury, and strategies to reduce the risk of head injury in youth soccer considering the available evidence and current youth soccer guidelines.

Methods

The literature was reviewed via PubMed search without date restriction in November 2014 and August 2015 using the terms 'soccer and concussion', 'heading and concussion', and 'youth soccer and concussion'. A number of 310 articles were identified and reviewed for applicable content specifically relating to youth athletes, heading, and/or acute or chronic brain injury from soccer. This paper summarizes the findings of the studies involving youth athletes, and a representative sample of those discussing heading biomechanics and adult studies evaluating the outcome of acute or chronic brain injury from heading.

Acute head injury/concussion

Despite the intentional use of the head to strike the ball in soccer, the risk of catastrophic head and neck injury in soccer

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is low compared to other sports. Between 1982 and 2008, the catastrophic injury rate in American football was 0.72 per 100,000 participants, boys soccer 0.08 per 100,000 participants, and girls soccer 0.02 per 100,000 participants.[11] High-school sports with a higher catastrophic risk than soccer include gymnastics, wrestling, lacrosse, cheer, baseball, track and field, and field hockey.

While the risk of catastrophic injury from soccer is low, the risk of concussion compared to other sports is high. There is limited data comparing concussion risk amongst youth sports but injury surveillance systems provide data for high-school and college athletes. In the National Collegiate Athletic Association (NCAA) women's soccer had the third highest concussion rate amongst college sports following only women's ice hockey and spring football.[12] Men's ice hockey was the same as women's soccer with a rate of 0.41 per 1000 athletic exposures. Football in the regular season had a rate of 0.37 and men's soccer 0.28. Gessel et al. [13] examined data from 15- to 24-year olds and found that football and soccer had the highest rates of concussion and that girls in general had higher rates than boys participating in the same sport.

Soccer injury studies have evaluated concussion in professional, college, high-school, and youth players of both genders and considered injuries occurring broadly through three mechanisms: Ball striking the head, head trauma other than ball impact in the act of heading the ball, or during play unrelated to heading. In adult professional players, women have a 2.4-fold higher rate of concussions than men. Women are more likely to have a head-to-head mechanism accounting for the concussion as opposed to a head-to-extremity mechanism in men. In professional studies, heading alone (ball to head contact only) is rarely identified as a cause of concussion.[14,15]

Boden et al. followed college-soccer players over 2 years and reported [16] no concussions from purposeful heading. The mechanisms were primarily head-to-head, body-to-head, or non-purposeful head-to-ball contact. Other studies of NCAA athletes report player-to-player contact in 84% of concussions sustained by men and 68% in women. These studies comment that purposeful heading was not the cause of any concussions although the results state that ball contact alone accounted for 8% of concussions in men and 18% in women.[17,18] Presumably, these were all non-purposeful head impacts with the ball.

Gessel in 2007 [13] found that amongst high-school players of both genders, about 40% of concussions occurred during heading. Boys were more likely to report contact with another person as causing the injury, and 18% of girls and 8% of boys reported contact with the soccer ball as the primary mechanism. Another large high-school study [9] found that concussions were most likely to occur in the act of heading with player-to-player contact accounting for 68.8% of boy's concussions and 51.3% of girl's concussions. Head contact with the ball accounted for 16% of boy's concussions and 28% for girls.

Our research in youth female players found that concussions predominantly occur through contact with another player, rather than from the ball itself.[10] Evaluating the cause of concussion amongst female youth players age 11–14, we found that 31% of concussions occurred in the act of heading. Contact with another player accounted for 54% and contact with the ball accounted for 30%. We also found that 86% of concussions occurred during games as opposed to training sessions.[10]

In summary, concussions in the act of heading are common, but it appears that for adult players the risk of concussion from heading is very low or absent. Youth players and females may be at higher risk for concussion that occurs primarily from player-to-player contact in the act of heading, rather than from heading the ball itself. The percentage of subjects identifying heading alone as the cause of their concussion increases though, as the age of the subjects decreases. This observation warrants further study.

Biomechanics of heading

Biomechanical assessment of heading forces offers a possible explanation for youth players' and females' increased risk of injury from heading a ball. Calculating the force transmitted to the brain during a header is complicated and influenced by a number of factors including: (1) size, weight, and inflation of the ball; (2) the size of the head and head stability as related to strength and technique; and (3) the angle at which the ball strikes and leaves the head.[19] Youth players have smaller heads, less trunk and neck strength to stabilize the head, and potentially poorer form with less efficient energy transfer from the head to the ball. As a result, their brains experience relatively greater angular acceleration forces from heading than the adult brain. To complicate matters further, standard models of head injury correlating linear acceleration with skull fracture are less relevant to concussion as angular acceleration correlates most highly with injury risk.[19] Naunheim et al. [20] calculated both linear and angular acceleration from heading balls at different velocities in young-adult males and found that the forces were below those considered necessary to cause concussion. This work is often cited arguing that heading does not cause concussion. It is unclear though whether this data can be extrapolated to children. Gutierrez et al. [21] studied female high-school soccer players performing 15 headers and found no difference in neurocognitive testing pre- and post-heading but did find that weaker isometric neck strength resulted in higher measured acceleration forces with headers. Hanlon and Bir [22] recorded head acceleration for age 13–14 girls in game play and found that linear accelerations were all below pre-established injury thresholds. On the other hand, three heading events resulted in angular accelerations above the injury threshold, although no concussions were diagnosed. This study illustrates the challenges of measuring head impacts and correlating them with injury. These studies suggest that the risks of heading are higher for children, particularly girls, compared to adults; however, there is no definitive evidence that proves this theory.

Chronic brain injury

Beyond concussion, there are studies suggesting that playing professional soccer in the latter half of the last century resulted in chronic brain impairment for many players. Tysvaer et al. [3] in 1991 compared 113 professional soccer

players with careers spanning from the 1960s through the 1990s to noncontact control subjects and found the soccer players had electroencephalogram abnormalities and significant neuropsychological deficits. Sortland et al. [4] reported brain computerized tomography results from players and found 18% had cortical atrophy and this finding was more common in self-reported 'headers'. Matser et al. [23] compared professional soccer players to swimmers and found neuropsychological deficits in the soccer players that correlated with concussion history, but the players did not report any concussions having occurred from heading alone. The sum of the early data led many to conclude that soccer, and specifically heading in soccer, caused chronic brain injury.

Subsequent studies have refuted that claim. Jordan et al. [6] followed US men's national team soccer players and a control group of track athletes comparing brain magnetic resonance imaging (MRI) and head-injury symptom questionnaires. The MRIs were not different comparing groups, and head injury symptoms correlated with past head trauma but not specifically heading. Staume-Naesheim et al. [5] performed neuropsychological testing on elite Norwegian players and found no correlation with prior heading history or concussion history. Stephens et al. [24] evaluated teen soccer and rugby players comparing neuropsychological testing performance to noncontact sport athletes and found no difference between the sports implicating heading, but head injury did predict reduced attention in both sports. In summary, most of the current literature fails to demonstrate neuropsychological deficits in former and current soccer players and most adult studies find that heading alone does not cause concussion. The chronic neuropsychological impairment identified in the older studies has been attributed to 'heavy' leather soccer balls that have been replaced by non-absorbent balls and also limited concussion awareness and treatment during the careers of those former players.

Neurocognitive changes from heading

Alternative methodology to determine the safety of heading has been to test subjects before and after acute bouts of heading. Gutierrez et al. [21] evaluated 17 US high-school girl players with neurocognitive testing before and after a bout of heading and found no difference. Kontos et al. [25] performed a similar study with both genders age 13–18 finding no relationship between soccer heading exposure and neurocognitive performance or concussion symptoms. There have been a number of studies assessing acute postural instability following bouts of heading. Broglio et al. [26] assessed postural stability in college players before and after bouts of rotational and linear heading. They found no postural impairment related to the heading. In a more recent study, Haran et al. [7] studying a mix of club and college players found that postural stability was impaired from 1 h through 2 days following a bout of heading. Interestingly, the subjects in the first study were heading balls at a higher velocity. Haran's results could be attributed to a more sensitive measure of postural instability and the inclusion of club players possibly with inferior-heading technique influencing his results.

A provocative study by Lipton et al. [8] in 2013 found heading at a certain threshold does result in brain injury and impaired function. He evaluated 37 players, primarily male with a mean age of 31. They completed a questionnaire regarding lifetime history of concussion and also they were asked to estimate the number of headers they experienced in the past year. The subjects had a brain MRI and neuropsychological testing. Concussion history was not associated with abnormalities on either of the tests, but those reporting more than 1800 headers per year had MRI abnormalities in temporal-occipital white matter microstructure and also impaired memory scores. The brain abnormalities were primarily located posteriorly and felt to be the result of contra-coup injury from heading occurring primarily anteriorly. They found a significant range in the number of headed balls per year from 32 to 5400 with a mean of 432. The findings were nonlinear suggesting that below a certain threshold heading was safe with the abnormal findings occurring above that threshold.

Summary

The current literature on youth heading is relatively reassuring regarding the risk of any significant brain injury from youth soccer but the studies are limited. Comparing soccer to other sports, the incidence of catastrophic head injury is low, but the concussion risk is relatively high. While the majority of concussions in children appear to resolve without sequelae, full recovery in children can be prolonged compared to adults and they should be managed conservatively. Rarely, concussions can lead to prolonged recovery with significant disruption in sports and school activities, and multiple concussions increase the risk for prolonged recovery and can lead to chronic brain injury.[27] At all levels of play, concussions are more likely to occur in the act of heading than with other facets of the game. While concussion from heading the ball without other contact to the head appears rare in adult players, some data suggest children are more susceptible to concussion from heading with biomechanical factors, less developed technique, and the immature brain's susceptibility to injury all potentially contributing.[9,10,13,21,22]

Injury prevention

Potential interventions to reduce the risk of head injuries in youth soccer include rules prohibiting or limiting heading for children, changes in training and coaching, and equipment modification. US Youth Soccer in 2013 developed heading guidelines [28] recommending no heading before age 10, teaching heading in a controlled environment using low-pressure or Nerf balls that are gently tossed to players, and limiting exposure and heading repetitions in young players. They also specifically state that children should not be forced to head the ball until they feel ready, and apprehension on the part of the players should be respected. In November 2015, the US Soccer Federation went further and as part of a legal settlement launched an initiative specifically banning heading for ages 10 and under and limiting heading to training only for children age 11–13.[29] How this will translate into rule changes and how it might be enforced are still unclear. Because children's maturation varies, age may not always be

the best indicator of when they are ready to head the ball. As youth players become bigger, stronger, and develop better heading technique, the forces to the brain imparted by a headed ball are relatively reduced, and a willingness to head the ball without coercion may be a good indicator of a player's developmental preparedness to head. Our study [10] of concussion in girls found that 86% of concussions occurred in game play suggesting that mastering heading in a controlled environment before allowing heading in games could be a useful strategy. There is also evidence in the professional ranks that about half of head injuries occur because of foul play.[30] It is critical that youth officials are trained and understand and enforce the rules regarding foul play that could contribute to injury. The first step in making soccer safer is to insure that existing guidelines and rules are followed.

The soccer ball has the potential to play a significant role in head injury. Smaller soccer balls are recommended for younger age groups and these guidelines should be followed. The inflation of the ball is also important as an over-inflated ball absorbs less energy with more force transmitted to the brain. Proper ball inflation should be assessed before games and training, and consideration should be given to underinflating balls for heading training.

Headgear to prevent head injury in soccer is controversial. Biomechanical data suggest that the deformation of padding in the headgear can decrease the force transmitted to the brain. However, the deformation of the ball is sufficient to minimize that effect during a header. In a head-to-head collision, the headgear deformation may be more relevant and the risk of laceration from head-to-head contact is lower using headgear.[31] Delaney et al. [32] in a retrospective study found that not wearing headgear resulted in increased risk of scalp laceration and a 2.65 increased risk of sustaining a concussion. A concern with headgear though is that it may result in more aggressive play increasing the concussion risk. A biomechanical study having women head the ball with and without headgear found that higher brain acceleration was found using the headgear.[33] Currently, there is insufficient evidence to recommend for or against using headgear to prevent concussion but ongoing research and product development may change in the future.

Lastly, if considering limiting participation in sports over injury risk, one must consider the risk on non-participation. Research has shown that children involved in sports have higher measures of physical health, report more positive health behaviors, have lower levels of depression and behavioral problems, and perform better academically.[34] Physicians and parents have an obligation to understand the risk of sport and try to minimize that risk whenever possible, but abandoning youth sports over injury concerns could leave children and teens engaged in activities or making decisions with more dire health consequences.

Conclusion

In summary, soccer is a low-risk sport for catastrophic head injury, but concussions are relatively common and heading often plays a role. Concussion from heading alone appears rare in adults, but may be more common in children, although more research is needed. Coaches and officials need to be educated regarding existing rules and regulations and how to identify concussions to insure that concussed players are removed from play and evaluated by trained professionals. Guidelines for ball size and inflation should be followed. Avoiding heading in games until a certain age seems warranted and the US Soccer Federation recently banned heading below age 11 and banned heading in games until age 14. While it seems reasonable to teach heading in controlled situations by age 11, the ideal age to allow heading in competitive play is unknown and readiness for heading should ideally be determined for each player based on their maturation, strength, and skill development.

Financial and competing interests disclosure

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

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