

Heading the Ball in Soccer: What's the Risk of Brain Injury?

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In Brief: Concern exists that heading the ball in soccer may cause brain injury. Studies using EEG, CT, neurologic exams, and neuropsychological testing have not clearly established that the practice is hazardous. Studies generally have shown no neuropsychological differences between soccer players and other athletes, but some have revealed differences between soccer players and nonathletes. Because of the uncertainties, the authors advocate use of correct heading technique, enforcement of game rules, and increased awareness of the potential for injury from heading the ball.

Sports-related head injuries occur at an estimated rate of 300,000 per year in the United States (1). Head trauma has been a particular concern for years in contact sports like boxing (2,3) and football. Guidelines such as the American Academy of Neurology's practice parameter on the management of concussion in sports (4) reflect physicians' concern about athletes in contact sports (see "Neurologists Offer Concussion Options," April 1997, page 25).

Soccer, classified as a contact sport by the American Academy of Pediatrics (5), has become a focal point for questions about repetitive head trauma. It is suggested that the deliberate use of the head to direct the soccer ball (heading) may be analogous to the repetitive blows to the head in boxing (6,7), which can give rise to syndromes involving pyramidal, extrapyramidal, and cerebellar signs, and sometimes cognitive impairment and personality change (2,8). If heading the ball can cause such syndromes, the implications would be serious, considering the estimated 16 million active soccer players in the United States and perhaps 40 million to 120 million worldwide (6,9,10).

The possible danger of brain injury from heading has led to investigations into the nature, mechanics, and possible long-term effects of the practice. Following is a review of the empirical literature, focusing primarily on the chronic, cumulative effects of heading, along with recommendations regarding protective measures.

Head Injuries in Soccer

Soccer has been called a relatively safe activity with an injury rate one-fifth to one-half of that in American football (9,10), but head injuries do occur. In Europe, head injuries

account for between 1% and 20% of all soccer injuries (7), and the literature contains reports of serious and even fatal head injuries in the sport (11-13).

Head trauma in soccer can occur in several ways, including a single hard blow from the ball (either accidental or from heading), contact with another player, striking the ground, collision with goalposts, and, possibly, repeated heading (6,9,11).

In a study of elite soccer players at the 1993 Olympic Festival (14), 89% (64) of the men were found to have some history of head injury, and 54% (39) had had concussions. The authors estimated that in a 10-year period, the likelihood of sustaining a concussion in soccer is 50% for men and 22% for women. While *properly executed* heading was not found to result in any concussive episodes, 18% (18 of 102) of the concussions were a result of heading.

National Collegiate Athletic Association (NCAA) soccer statistics indicate a concussion rate of 0.14 per 1,000 athletic exposures for men and 0.15 for women (6). More recently, Boden et al (15) reported higher rates in elite college soccer players: 0.60 for men and 0.40 for women. They reported no concussions resulting from heading the ball.

Grounds for Concern

Two factors that have generated concern about heading are the reports of heading-related symptoms, some of which suggest the possibility of mild concussion, and the risks of successive minor concussions.

A significant number of symptoms were reported in a survey by Tysvaer and Storli (11) of 128 active Norwegian soccer players. The athletes, who had played an average of 100 games each, reported both "protracted" and permanent symptoms, including headache, neck pain, and dizziness (table 1). In addition, Matthews (16) reported migraine headaches associated with heading.

Table 1. Protracted and Permanent Symptoms Reported by 128 Norwegian Soccer Players After Soccer Ball Heading (11)

Symptom	Protracted (No.)	Permanent (No.)
Headache	12	2
Neck pain	6	0
Dizziness	5	1
Irritability	1	1
Insomnia	1	1
Hearing disturbance	1	0

Weakened memory	0	2
Abnormal alcohol reaction	0	1

The concern about heading has been heightened by findings regarding the effects of multiple concussions. Although most minor head trauma symptoms may resolve in minutes, hours, or days (12,17), apparent recovery does not ensure that neurons have not been damaged or that an initially negligible condition will not be exacerbated by further damage (11). Each event may reduce the "neuron reserve," creating a deficiency that may become evident with future injury (18).

In animal research, moderate repetitive blows at brief intervals have been shown to cause more severe brain damage than intense blows at intervals of days to weeks (19). In addition, Gronwall and Wrightson (18) showed in 20 adults aged 16 to 26 that information processing was reduced to a significantly greater extent after a second concussion than after the first, and that the effects lasted longer.

The neurologic and cognitive effects of repeated minor head injuries may be dose-related and cumulative when the injuries occur over extended periods. But repeated head injuries occurring over an interval of hours or days can be fatal, as in the second-impact syndrome (16). (See "Second Impact Syndrome: A Risk in Any Contact Sport," June 1995, page 27.)

The Physics of Heading

Factors described as possible influences in injury from heading include the characteristics of the ball, frequency of impact, physics of ball contact, and technique of heading.

A soccer ball weighs 14 to 16 oz (396 to 453 g) and has an inflated pressure of 14.7 lb/sq in. (about 1 kg/cm²), or 1 atmosphere at sea level). It can travel at speeds of 37 to 74 mph or more. A ball kicked from 11 yd (about 10 m) at half power travels at 52 mph and strikes with an impact of 116 kiloponds (kp). At full power, impact is estimated at 200 kp, and contact with the ball lasts from 1/128 to 1/63 second. Traditional leather balls can increase in weight up to 20% when wet, though this is not an issue with modern synthetic balls. A soccer ball striking the head has less impact than a typical boxing punch, producing a head acceleration of 20g vs 100g for a punch (6,8,11).

Estimates of the number of times a soccer player heads a ball vary from an average of 5 per game (350 per year in a 70-game season), to 6.67 per game (2,000 in 300 games), to 9.05 times per practice and 7.85 times per game (6,8,11,14). It has been suggested that European players head most frequently and that heading occurs the least in US indoor soccer.

The risk and severity of heading injuries are related to the impact force of the ball and consequent acceleration of the player's head. Studies conducted on animals have shown

that concussion is induced with difficulty when the head is held in a fixed position but more easily when the head is allowed to move freely (8,11).

Correct heading involves use of the frontal bone to contact the ball, the neck muscles to restrict head motion, and the muscles of the lower body to position the torso in line with the head and neck to increase the resistant mass and decrease acceleration of the head (figure 1). For technically correct heading, therefore, correct positioning and conditioning of the entire body, including muscles used in jumping, have been recommended (8,20).

Figure 1: Courtesy of Robert C. Schwartz, MD



Figure 1. For proper heading technique, the player uses the frontal bone to contact the ball, the neck muscles to restrict head motion, and the muscles of the lower body to position the torso in line with the head and neck to increase the resistant mass and decrease acceleration of the head. To reduce the possibility of head injuries, soccer players should learn correct positioning and condition the entire body.

Despite the protection offered by correct technique and adequate conditioning, a study of four elite players using correct heading technique (7) resulted in reporting of headaches by all four after 10 minutes of heading. In addition, Barnes et al (14) reported that half of the Olympic soccer players studied had at least one headache after heading; they also reported worsening of headaches with exertion, throbbing headaches, and bilateral symptoms. The players typically ascribed symptoms to poor heading technique.

The use of helmets in soccer has been suggested, but it has been recognized that this approach is unlikely to be adopted (9). In addition, helmet use may not effectively diminish acceleration-type injuries (15).

Studies of Chronic Effects

A number of attempts have been made to research the question of potential consequences of heading, with active and retired soccer players serving as both the focus of study and as controls for researching similar issues in other athlete populations. Methods used have been self-reporting, neuroradiologic studies, and neurologic and neuropsychological evaluation. The results of these studies have been mixed.

EEG evaluation. Tysvaer and Storli (7) used a neurologic and electroencephalographic (EEG) approach. They studied 69 active Norwegian First Division soccer players (aged 15 to 34), 10 of whom considered themselves to be typical headers, and a control group of 69 age-matched men from various occupations with no history of neck or head injury and no soccer experience.

The study participants' EEGs were classified as normal when background activity was within the normal range and regular alpha activity was 8 to 12 Hz. EEGs were considered slightly abnormal with focal, or localized, activity slower than 8 Hz but not to a grade considered definitely abnormal. Results were classified as abnormal with focal episodes of 4 to 7 Hz and/or background activity below 8 Hz.

The results showed that abnormal EEGs were more numerous among players than among controls: 87% (60) of the control group's EEGs were normal vs 65% (45) of the soccer players' ($p < .001$). Among controls, 7% (5) had a slightly abnormal EEG and 6% (4) had an abnormal EEG, compared with 25% (17) and 10% (7), respectively, for the athletes. However, none of the typical headers showed abnormal EEGs. Abnormal EEGs were more common in younger players, which the authors attributed to a greater susceptibility to trauma, skeletal immaturity, or possibly less experience and skill.

Players with heading-related symptoms had a higher percentage of abnormal EEGs than players without symptoms (16% vs 3%), but this difference was not significant.

The neurologic exam was normal in all but one player, suggesting that it may not be particularly sensitive in this situation.

CT study. Sortland and Tysvaer (19) evaluated 33 former Norwegian First Division soccer players using computed tomography (CT). The players, who averaged 52 years old, had played an average of 329 games and had quit playing an average of 18 years previously.

Visual evaluation of CT scans revealed that 27% (9) of the players had definitely widened ventricles and 9% (3) had questionable widening. On visual grading, 33% (11) had central and/or cortical atrophy. Nine typical headers, who were significantly older, also had the highest frequency of atrophy. The authors noted that the findings on visual evaluation exceeded the frequencies observed in a study of the Danish general population.

Neuropsychological testing. Tysvaer and Lochen (21) used a neuropsychological approach in comparing 37 former Norwegian National Team soccer players with 20 hospitalized patients as controls. The average age of the soccer players was 48.6 years. They had ended their careers an average of 14 years prior to examination, had a per-player average of 359 games, and were not abusing alcohol. The control patients averaged 45.2 years of age and had no history of neck or head injury.

Neuropsychological tests included the Wechsler Adult Intelligence Scale (WAIS), Trails A & B, the Halstead-Wepman-Reitan Aphasia Screening Test, the Benton Visual Retention Test, a sensory-motor perception test, and a hemispheric function test.

Results indicated that intra-individual differences in WAIS Verbal-Performance subtest scores were greater in soccer players than in the control group. (In the absence of cognitive problems, an individual's scores on the verbal-performance subtests are expected to be about equal.) Thirty-five percent (13) of players vs 10% (2) of controls

had a split of 14 or more points. Soccer players also scored less well on Trails A & B than controls.

The authors used a "key score" to synthesize the neuropsychological results, a method they report to be 83% to 91% accurate. Using this approach, 81% (30) of the soccer players demonstrated some degree of neuropsychological impairment, compared with 40% (8) of the controls. Headers had a higher (though not significantly higher) frequency of "severe" or "severe to gross" neuropsychological impairment than non-headers (20% vs 8%). Key score results of soccer players vs controls are presented in table 2.

Table 2. Neuropsychological Impairment in 37 Middle-Aged Former Soccer Players and 20 Nonathlete Controls (21)

Degree of Impairment*	Soccer Players	Controls
Severe to gross	3% (1)	0
Severe	8% (3)	0
Moderate	38% (14)	0
Mild	32% (12)	40% (8)
None	19% (7)	60% (12)

Measured as a "key score" derived from a battery of neuropsychological tests.

MRI scanning. S. Jordan et al (6) used magnetic resonance imaging (MRI), a heading frequency index, and symptom reports in comparing 20 members of the US National Soccer Team (mean age, 24.8 years) with 20 elite male track-and-field athletes (mean age, 26.4 years). The authors sought to control for alcohol use, history of head injury, and neurologic illness such as migraine.

Results indicated that only prior acute head injury correlated with symptoms reported by players. No dose-response relationship was found between heading and severity of symptoms. Forty-five percent (9) of soccer players had abnormal MRI findings including cortical atrophy, focal atrophy, and cavum septum pellucidum (CSP), and 30% (6) of controls had comparable findings. The difference was not considered significant. The authors note that despite their finding of a lack of relationship between heading and symptoms, they could not rule out the possibility that heading exacerbates previous injury or that encephalopathic changes will occur later in life.

Other studies. Thomassen et al (22) reported EEG, neurologic, and neuropsychological test results in 53 former champion amateur boxers and 53 former first-division soccer players. Forty-five percent (24) of boxers and 70% (37) of the soccer players had slight

symptoms, especially involving concentration or memory impairment. The only positive finding was decreased motor speed in the left hand of the boxers. No relationship was found between symptoms and objective measures in either of the groups, and there was no correlation of findings with symptoms in boxers who had had head trauma.

Haglund and Eriksson (2) studied brain damage in boxers and used soccer players and track athletes as controls. EEG abnormalities were seen in 20% (5 of 25) of the soccer players. This was not significantly different from boxers (32% for boxers with frequent bouts, 36% for boxers with less frequent bouts) or track athletes (12%). No severe EEG abnormalities were found. The only positive neuropsychological finding was decreased finger-tapping speed bilaterally in boxers.

Interpreting the Studies

In view of the wide variety of research approaches and the inconsistent findings to date, an answer to the question whether heading the ball causes brain injury remains elusive. Overall, the evidence suggests that there are reasons for concern and findings that need further exploration, but the potential for injury from heading has not been clearly established.

Of most concern are the following:

- soccer players' reports of increased neurologic symptoms such as headaches, heading-related migraine, neck pain, and dizziness (7,11,14,16);
- the report by Tysvaer and Lochen (21) of neuropsychological changes in soccer players as compared with hospitalized controls;
- neurodiagnostic findings of ventricular changes and atrophy in 10% to 33% of former soccer players (19);
- MRI changes in 9 of 20 members of the US National Team, some with focal atrophy (6); and
- more-frequent abnormal EEGs in active soccer players as compared with male nonathletes (7).

In addition, B. Jordan (23) notes that the incidence of CSP in the US Team study (6) was 15%. He observes that this exceeds the 1% typically found in the general population and the 13% found among professional boxers, and suggests that CSP in boxers results from repetitive head trauma.

On the other hand, the above findings are rendered less meaningful by other data, often from the same studies (24). For example, the headache reports come from a very limited number of athletes, and the reported neurologic symptoms are based on subjective recall (7,11,16,23).

Also, the implications of the reported neuropsychological changes in middle-aged and older former soccer players are not clear (21). With an average elapsed time since playing of 14 years, many variables could have influenced the results in the interim (21). Further, both Barnes et al (14) and Boden et al (15) point out that non-heading-related

concussions and head injuries in soccer could contribute to neuropsychological changes and thus could confound assessment of the effects of heading the ball.

The finding of abnormal MRI scans in 9 of 20 US National Team members is counterbalanced by the similar results in 6 of the 20 elite track athletes who served as controls and is complicated by histories of nonheading head injuries in both groups (6). In response to concerns raised by B. Jordan (23) about the presence of CSP in US Team members, S. Jordan et al (24) indicate that the lesions found were so small as to be clinically insignificant and were unrelated to a history of heading or concussion.

Although Sortland and Tysvaer (19) found more cortical atrophy among headers, the headers were also significantly older than nonheaders. The significance of abnormal EEGs is diminished by the finding of Tysvaer and Storli (7) that there were no EEG differences between players with neurologic symptoms and those without, and that all the abnormal EEGs were found in players who were not typical headers.

Other studies also seem to mitigate concerns about heading. Haglund and Eriksson (2) did not find significant CT changes in active or former soccer players who were controls in their study of boxers; and while EEG changes were found in soccer players, they were also found in track-athlete controls as well as in the boxers. Thomassen et al (22), in comparing boxers and former soccer players, found no correlation between objective measures and symptoms.

Thus, the scattered positive findings seem to be muted, though certainly not refuted. The potential negative effects of heading in young players and on the developing brain should still be a concern. Could heading, when begun at an early age, lay a foundation for the neuropsychological changes seen later in life? No data address this.

Further, while in general no significant differences have been found among athlete groups studied, differences have been found when soccer players were compared with nonathlete controls (7,19,21). Do athletes have in common some history or experience on or off the field that might account for such variances?

Precautions Warranted

Therefore, while heading a soccer ball has not been proved hazardous, caution is warranted until more definitive evidence becomes available. Given the present knowledge, four steps seem appropriate.

First, education should be enhanced to increase awareness of the *potential* for injury from heading a soccer ball. This information needs to be imparted to coaches, parents, and referees, as well as healthcare professionals.

Second, correct heading technique must be emphasized and promoted. While some accidental injuries, such as those from goalpost collisions, may be unavoidable, proper technique for preventing injury can be used consistently.

Third, rules that protect players should be enforced by referees and supported by coaches, parents, and fans. For example, referees should ensure that defenders maintain the full required distance from the ball on restarts and should not allow encroachment, which decreases defenders' distance from the ball and increases impact.

Fourth, physicians should continue to appreciate the potential for brain injury from heading. Appropriate sideline evaluation of athletes for concussion should be part of care. Additionally, calls from parents or players about symptoms after a game or injury should be addressed and evaluated, and, when appropriate, concussion should be part of the differential diagnosis.

Finally, still needed are controlled prospective studies with an emphasis on the *clinical* significance of any positive findings.

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