REVIEW

doi: 10.5455/medarh.2017.71.356-359
MED ARCH. 2017 OCT; 71(5): 356-359
RECEIVED: AUG 10, 2017 | ACCEPTED: OCT 05, 2017

[1]Clinical Department of Neurosurgery, University Medical Centre, Maribor, Slovenia

Corresponding author: Tomaz Velnar, Clinical Department of Neurosurgery, University Medical Centre Maribor, Ljubljanska ulica 5, 2000 Maribor, Slovenia. Telephone: +386 2 321 1457. Fax: +386 2 332 4830. E-mail: tvelnar@hotmail.com

May Heading in Soccer Result in Traumatic Brain Injury? A Review of Literature

Gorazd Bunc, Janez Ravnik, Tomaz Velnar

ABSTRACT

Background: Globally, soccer is the most popular team sport, unifying many fans all around the world. The epidemiological studies so far have confirmed that head playing and hitting the ball with head may cause minor head injuries, which exert their effects in a cumulative way. **Methods:** Literature search for this review was conducted and data about traumatic brain injury collected from various sources. **Results:** The consequences of head injury are evident as chronic changes in cognition, including disturbances in concentration and slowing of mental and physical agility. **Conclusion:** Various recommendations have been issued for the prevention of chronic negative cumulative effects of soccer ball head playing. In addition, the professional soccer players are also exposed to more intense craniocerebral trauma, such as concussions and contusions. These patients require treatment of skilled sports physicians, neurologists and neurosurgeons and some may need long to return to the sport scene again.

Keywords: head injury, brain injury, soccer, concussion, head.

1. INTRODUCTION

Globally, soccer is the most widespread and most popular collective sport according to the number of participants and fans. The International Federation of Association Football (FIFA) reports of over 224 million active players, registered at national associations in 204 countries (1). It was already in 1424 when the Scottish king James I. tried to forbid the so-called fute ball, as the young men were more drawn to the game instead of the important medieval fighting sports, such as fencing and archery. As seen, the sport was already popular in those times and probably existed in a certain form much earlier (2).

Playing or hitting the ball with the head comes from the north of England. It became more and more popular a decade after the original rules were adopted by the Football Association in 1863. Soon afterwards in 1872, the association added a new rule forbidding the ball contact with hands (3). Since then, the so-called head playing became the integral part of soccer. It is therefore not unusual that speculations began to be made whether in addition to the already existing dangers of footballers colliding during the play with different body parts against the head or head to head, the possibility of causing short-term and long-term head trauma by hitting or playing with the head exists (4, 5). Further considerations and extensive studies are being conducted to establish to what extent, from which direction and on which side consequences are possible and if these are long-term or whether they are visible immediately (4-6).

Soccer has been known as a typical contact sport with a relatively high level of exposure to head injuries only the last few years (7-16). The American Paediatric Academy postulated soccer as a contact or cohesion sport in the same category as the American football and ice hockey with a comparable frequency of head injuries (17, 18).

2. METHODS

Literature search was conducted for this review and data about traumatic brain injury collected from various sources. These included electronic databases Medline and Science Direct. The search was performed using a combination of the following terms: head injury, brain injury, craniocerebral trauma, soccer, football, concussion, cognitive function, head and age (1, 5, 19-28). Various mechanisms of head trauma

in soccer and the consequences are summarised and discussed in the article.

3. RESULTS AND DISCUSSION

As a typical contact sport, soccer may result in various injuries. The majority of them affect talocrural joint, knee or inguinal region, however; 4% to 22% of all soccer injuries are related to head injuries with the incidence of 1.7 injuries per 1000 playing hours (7-13). This number refers to all types of head injuries, including facial injuries, concussions, bruises and eyeball injuries. The incidence of concussions is estimated at 0.5 injuries per 1000 competitive soccer playing hours, although it is difficult to provide a more accurate estimation due to inconsistencies in different interpretations of concussions (5, 8, 14, 15).

Mechanisms of injury

Head injuries in soccer may result from two possible mechanisms (5, 19). As in other contact sports, head injuries mostly result from unintentional hits with the head and hits to the head from different body parts of players (head to head, elbow to head), hitting the head against the ground, football goal frame or even hits received by the ball, when the ball flies and hits the unprepared player with great speed (5, 19-21). The other reason for head injuries in soccer includes forces that are below the level required to trigger the symptoms of concussion. In such cases, the terms microtrauma and subconcussive brain trauma are used (5, 22, 23). Such injuries result from intentional bouncing of the ball with the aim of controlling and re-directing or even accelerating its movement towards a target (5, 19). The impact of such subconcussive brain injuries is most probably cumulative and chronic, but less acute. The number of hits with the head is also important. It was found that professional players hit the ball with their head between six to sixteen times per match. The more successful the players, the more exposed they are to high intensity training and higher frequency of matches. For a footballer's professional career, which last up to 20 years, this represents an important cumulative burden of hits with the head (19-21, 25).

Researchers report of four different mechanisms having impact on the development of neuropathological changes in acute brain trauma caused in boxing and other contact sports, as well as in soccer (19, 25, 26). The mechanisms include rotational and angular acceleration, linear acceleration and carotid artery injuries (25, 26). Rotational and angular acceleration injuries are particularly dangerous as they include sudden acceleration of the head with simultaneous rotational movements of the brain inside the skull, which may lead to vessel injuries due stretching and occlusion. This mostly occurs in bouncing the ball with the head (19, 22, 23, 25, 27). In addition, it is very important how the soccer player is capable of limiting the rotational movements with proper contraction of neck muscles and which techniques are used to hit the ball with the head, as specifically pointed out by the Norvegian neurosurgeons (28). Linear acceleration causes focal ischemic brain lesions, which worsen proportionally with the number of microtraumatic subconcussive hits (20, 21, 28).

Clinical and diagnostic findings

Norwegian researchers report of electroencephalographic (EEG) abnormalities and an increased incidence of brain atrophy in active and former professional soccer players compared to persons who do not play soccer actively. Cognitive and emotional symptoms, typical for postcommotional syndrome, are also more frequent (28-30). One third of active and former professional soccer players had a minor to moderately altered EEG recordings. It is interesting that less EEG abnormalities were found in soccer players, who characterized themselves as typical players with the head (28, 31). This paradox probably points to better endurance, training and experience of such players and superior technique of playing with the head compared to others. Defence players were more burdened than other players. EEG abnormalities were much more expressed in younger soccer players and may be attributed to neuronal injury of still developing brain, caused by subconcussive injuries (19, 27-30).

On the other hand, studies that included the recordings of the head with computer tomography and magnetic resonance did not show any reliable correlation between postcontusional or postcommotional symptoms and signs of possible encephalopathy (32). A correlation between morphological changes and previous brain injuries in soccer players has been established (19, 30). It was concluded that repeated microtrauma caused by hitting the ball with the head and other less intensive blows to the head are not clinically significant (27, 29, 31, 33, 34). Modern literature questions the findings of these older studies due to many methodological imperfections, such as lack of data on the condition prior to injuries, subjectivity of researchers, insufficient control (35) ... This should be further investigated. A large share of injuries described by Tysvaer may explain the possibility of brain damage caused by alcohol which displays a similar image, however; this possibility was not excluded in the study (28, 36).

Certain prospective controlled studies, which also included the subject's clinical status, neuropsychological testing and imaging, exclude the correlation between the cognitive disorders and soccer playing (32, 34, 37, 38). On the other hand, certain other studies established a statistically significant poorer performance of neuropsychological tests in soccer players compared to rugby players and sportsmen from non-contact sports at non-professional level (27, 35). These studies undoubtedly establish a correlation between the cumulative effect of bouncing the ball with the head and poorer neuropsychological test results (27, 35, 39). Interestingly, some reports describe a clear correlation between increased serum concentration of biochemical markers, typical for brain trauma, such as S-100B and neuron-specific enolase and the intensity of playing with the head or bouncing the ball with the head during soccer (40-43). Serum concentration increases of these two markers are transient, however; statistically significantly increased in soccer players after a match compared to serum levels prior to

the match (42-43). The studies and scientific evidence are summarised in Table 1.

Recommendations for the game

Regarding the above mentioned, The Canadian Academy of Sport Medicine has laid down recommendations with the purpose to decrease the frequency of head injuries in soccer players, including concussions (44). These recommendations are: soccer is a contact sport where concussions are possible and severe head injuries as well; the players should avoid dangerous actions; all participating in soccer have to acquainted with the signs and symptoms of head injuries and proper training needs to be carried out prior to soccer season; all players with suspected concussions have to be examined and treated by specially trained physicians; soccer balls and their size has to be adjusted according to age and properly inflated. The smallest soccer ball size, number 3, is recommended for children under the age of 10, number 4 for children between 10 and 14 years, and the biggest, number 5, for players above 14 years. Children should strictly avoid hitting the ball with the head, especially repeated hitting, due to so far unclear short and long-term effects of bouncing the soccer ball with the head. It is important to teach the players the right technique with minimum traumatizing effect; the soccer goal frame should be firmly ingrained and padded if possible; goalkeepers, who are the most exposed to potential brain trauma, have to be extra protected against the players' offense play. During the game the goalkeepers have to wear mouth guard. Wearing a special head guard is not obligatory so far, as it is not known yet whether its use is beneficial in all cases (16, 19, 21, 35, 44-47).

4. CONCLUSION

European Soccer is undoubtedly recognized as a contact sport with statistically comparable frequency of craniocerebral injuries as in American football and hockey (5, 6). The injuries may be severe and include skull fractures and in rare cases also contusions and hematomas. Head trauma is assessed according to a special sport-specific definition. The mildest level is a simple concussion, which does not require any other measures than a rest. In a complicated concussion, the symptoms last longer and manifest themselves as the disturbance of consciousness and long-lasting cognitive disorders. Such patients require the treatment of specially trained sport physicians and cannot expect to return to the field any time soon. To avoid the possibility of chronic cumulative negative effect of bouncing the ball with the head, different recommendations were created and the playing technique must be correct.

- **Conflict of interest:** Authors have no conflict of interest.
- **Authors contributions:** Gorazd Bunc and Janez Ravnik designed the study and collected the literature, Tomaz Velnar designed the study, was scientific advisor and reviewed the work.

REFERENCES

1. Guthrie RM. Emerging data on the incidence of concussion in football practice at all levels of amateur play. Phys Sportsmed. 2015; 43(4): 333-5. doi:10.1080/00913847.2015.1081552
2. MacNish M. The Story of Scotland. 1st ed. Glasgow: Sunday Mail; 1988.
3. Bangsbo J, Norregaard, Thorsoe, F. Activity profile of competition football. Can J Sport Sci. 1991; 16(2): 110-6.
4. Pickett W, Streight S, Simpson K, Brison RJ. Head injuries in youth soccer players presenting to the emergency department. Br J Sports Med. 2005; 39(4): 226-31. doi:10.1136/bjsm.2004.013169
5. Kirkendall DT, Jordan SE, Garrett WE. Heading and head injuries in soccer. Sports Med. 2001; 31(5): 369-86.
6. Delaney JS. Head injuries presenting to emergency departments in the United States from 1990 to 1999 for ice hockey, soccer, and football. Clin J Sport Med. 2004; 14(2): 80-7.
7. Sandelin J, Santavirta S, Kiviluoto O. Acute football injuries in Finland in 1980. British Journal of Sports Medicine. 1985; 19(1): 30-3.
8. Andersen TE, Arnason A, Engebretsen L, Bahr R. Mechanisms of head injuries in elite football. Br J Sports Med. 2004; 38(6): 690-6. doi:10.1136/bjsm.2003.009357
9. Movrin I, Cretnik A. Surgical management of traumatic spondylolisthesis of the axis. Acta medico-biotechnica. 2013; 6: 53-7.
10. Klemenc-Ketis Z, Kersnik J. One month prevalence of self-reported musculoskeletal pain syndromes and correlates. Acta medico-biotechnica. 2012; 5: 40-6.
11. Kuhta K, Pahor D, Mechanisms and prevention of open globe eye injuries. Acta medico-biotechnica. 2015; 8: 32-8.
12. Fokter SK, Dovnik A, Fokter Dovnik N. Surgical treatment of acute patellar dislocation associated with bony avulsion in children. Acta medico-biotechnica. 2013; 6: 21-9.
13. Hussein M, Cretnik A, Dinevski D, Rupreht M, Vogrin M. Arthroscopic anatomy and pathoanatomy of anterior cruciate ligament ruptures: clinical study with 94 patients. Acta medico-biotechnica. 2013; 6: 45-50.
14. Delaney JS, Lacroix VJ, Lecler S, Johnston KM. Concussions among university football and soccer players. Clin J Sport Med. 2002; 12(6): 331-8.
15. Strojnik T, Velnar T, Krcevski Skvarc N. The spinal cord stimulation an effective treatment for failed back surgery syndrome? Our experience with 21 cases. Acta medico-biotechnica. 2010; 3: 25-34.
16. Babbs CF. Biomechanics of heading a soccer ball: implications for player safety. Scientific World Journal. 2001; 1: 281-322. doi:10.1100/tsw.2001.56
17. Spiotta AM, Bartsch AJ, Benzel EC. Heading in soccer: dangerous play? Neurosurgery. 2012; 70(1): 1-11. doi:10.1227/NEU.0b013e31823021b2
18. American Academy of Family Physicians; American Academy of Orthopaedic Surgeons; American College of Sports Medicine; American Orthopaedic Society for Sports Medicine; American Osteopathic Academy of Sports Medicine; American Medical Society for Sports Medicine. The team physician and conditioning of athletes for sports: a consensus staetment. Med Sci Sports Exerc. 2001; 33(10): 1789-93.
19. Levy ML, Ozgur BM, Berry C, Aryan HE, Apuzzo ML. Analysis and evolution of head injury in football. Neurosurgery. 2004; 55(3): 649-55.
20. Pellman EJ, Viano DC, Tucker AM, Casson IR, Waeckerle JF. Concussion in professional football: reconstruction of game

impacts and injuries. Neurosurgery. 2003; 53(4): 799-814.
21. Viano DC, Casson IR, Pellman EJ. Concussion in professional football: biomechanics of the struck player-part 14. Neurosurgery. 2007; 61(2): 313-28. doi:10.1227/01.NEU.0000279969.02685.D0
22. Nilsson M, Hägglund M, Ekstrand J, Walden M. Head and neck injuries in professional soccer. Clin J Sports Med. 2013; 23(4): 255-60. doi:10.1097/JSM.0b013e31827ee6f8
23. Erlanger D, Kuntner K, Barth J, Barnes R. Neuropsychology of sports-related head injury: Dementia Pugilistica to Post Concussion Syndrome. Clinical Neuropsychology. 1999; 13: 193-209.
24. Pellman EJ, Viano DC, Tucker AM, Casson IR. Concussion in professional football: location and direction of helmet impacts-Part 2. Committee on Mild Traumatic Brain Injury, National Football League. Neurosurgery. 2003; 53(6): 1328-41.
25. Jordan S, Green E, Galantly H, Mandelbaum B, Jobour B. Acute and chronic brain injury in United States National Team Football Players. American Journal of Sports Medicine. 1996; 24(2): 205-10. doi:10.1177/036354659602400216
26. Lampert PW, Hardman JM. Morphological changes in brains of boxers. JAMA. 1984; 251(20): 2676-9.
27. Kirkendall DT, Garrett WE Jr. Heading in Soccer: Integral Skill or Grounds for Cognitive Dysfunction? J Athl Train. 2001; 36(3): 328-33.
28. Tysvaer AT, Storli OV. Soccer injuries to the brain. A neurologic and electroencephalographic study of former players. Acta Neurol Scand. 1989; 80(2): 151-6.
29. Pellman EJ, Powell JW, Viano DC, et al. Concussion in professional football: epidemiological features of game injuries and review of the literature-part 3. Neurosurgery. 2004; 54(1): 81-96.
30. Sortland O, Tysvaer AT. Brain damage in former association football players. An evaluation by cerebral computed tomography. Neuroradiology. 1989; 31(1): 44-8.
31. Barnes BC, Cooper L, Kirkendall DT, McDermott TP, Jordan BD, Garrett WE Jr. Concussion history in elite male and female soccer players. Am J Sports Med. 1998; 26(3): 433-8. doi:10.1177/03635465980260031601
32. Straume-Naesheim TM, Andersen TE, Dvorak J, Bahr R. Effects of heading exposure and previous concussions on neuropsychological performance among Norwegian elite footballers. Br J Sports Med. 2005; 39(1): 70-7. doi:10.1136/bjsm.2005.019646
33. Jordan SE, Green GA, Galanty HL, Mandelbaum BR, Jabour BA. Acute and chronic brain injury in United States National Team soccer players. Am J Sports Med. 1996; 24(2): 205-10.
34. Guskiewicz K, Maskell S, Broglio S, Cantu R, Kirkendall D. No evidence of impaired neurological performance in collegiate soccer players. Am J Sports Med. 2002; 30(2): 157-62. doi:10.1177/03635465020300020201
35. Straume-Naesheim TM, Andersen TE, K Holme IM, McIntosh AS, Dvorak J, Bahr R. Do minor head impacts in soccer cause concussive injury? A prospective case-control study. Neurosurgery. 2009; 64(4): 719-25. doi:10.1227/01.NEU.0000340681.12949.6D
36. McCrory PR. Brain injury and heading in soccer. BMJ. 2003; 327(7411): 351-2. doi:10.1136/bmj.327.7411.351
37. Jordan BD. Acute and chronic brain injury in United States national team soccer players. Am J Sports Med. 1996; 24(5): 70-5. doi:10.1177/036354659602400526
38. Putukian M, Echemendia R, Mackin S. The acute neuropsychological effects of heading in soccer. Clin J Sports Med. 2000; 10(2): 104-9.
39. Rutherford A, Stephens R, Potter D, Fernie G. Neuropsychological impairment as a consequence of footbal (soccer) play and football heading: preliminary analyses and report on university footballers. J Clin Exp Neuropsychol. 2005; 27(3): 299-319. doi:10.1080/13803390490515504
40. Mussack T, Dvorak J, Graf-Baumann T, Jochum M. Serum S-100B protein levels in young amateur soccer players after controlled heading and normal exercise. Eur J Med Res. 2003; 22(8): 457-64.
41. Straume-Naesheim TM, Andersen TE, Jochum M, Dvorak J, Bahr R. Minor head trauma in soccer and serum levels of S100B. Neurosurgery. 2008; 62(6): 1297-306. doi:10.1227/01.neu.0000333301.34189.3d
42. Stalnacke BM, Tegner Y, Sojka P. Playing soccer increases serum concentrations of the biochemical markers of brain damage S-100B and neuron-specific enolase in elite players: a pilot study. Brain Injury. 2004; 18(9): 899-909. doi:10.1080/02699050410001671865
43. Stalnacke BM, Ohlsson A, Tegner Y, Sojka P. Serum concentrations of two biochemical markers of brain tissue damage S-100B and neurone specific enolase are increased in elite female soccer players after a competitive game. Br J Sports Med. 1006; 40(4): 313-6. doi:10.1136/bjsm.2005.021584
44. Delaney JS, Frankovich R. Head injuries and concussions in soccer. Clin J Sport Med. 2005; 15(4): 216-9.
45. McCrory P, Johnston K, Meeuwisse W, et al. Summary and agreement statement of the 2nd international conference on concussion in sport, Prague 2004. Br J Sports Med. 2005; 39(4): 196-204. doi:10.1136/bjsm.2005.018614
46. Harmon KG, Drezner JA, Gammons M, et al. American medical society for sports medicine position statement: concussion in sport. Br J Sports Med. 2013; 47(1): 15-26. doi:10.1136/bjsports-2012-091941
47. Gavett BE, Stern RA, McKee AC. Chronic traumatic encephalopathy: a potential late efect of sport-related concussive and subconcussive head trauma. Clin Sports Med. 2011; 30(1): 179-88. doi:10.1016/j.csm.2010.09.007