

Protective Equipment and the Prevention of Concussion — What Is the Evidence?

Rodolfo R. Navarro, MD

Abstract

The complex nature of the evaluation and management of concussion lends to controversy, and the immediate and long-term implications still are being investigated. Various types of protective equipment have been used as a means to prevent concussions, and protective equipment is being used more frequently in different sports. Recent investigations have suggested that a protective, but not preventive, effect may be afforded by mouthguard use in rugby players, headgear use in soccer players, and customized mandibular orthotic use in football players. The use of faceshields has not shown a proven benefit in preventing the incidence of sport-related concussion in ice hockey or field hockey participants. Further studies are needed to clarify the role of protective equipment in the prevention of sport-related concussion.

cussions (22). As well, there has been significant interest in protective head and facial equipment in other sports, such as skiing, soccer, lacrosse, and pole vaulting (5,40). The short-term and possible long-term ramifications of sport-related concussion can be burdensome to many athletes, and thus the prevention of any sport-related concussion is ideal. This review summarizes recent literature on the use of protective equipment for the prevention of sport-related concussions.

Introduction

Increasing interest in sports-related concussion has recently spread, and the long-held notion of benign “dings” and “bell-ringers” has been cast aside. At the professional level, for example, the National Football League (NFL) has adopted a more strict policy on concussions and return-to-play (3). Additionally, beginning in the 2010 to 2011 season, NFL team locker rooms will carry posters with newer and more definitive language regarding the severity of sport-related concussions (4). Increasing numbers of professional bull riders and rodeo participants are using helmets in an attempt to prevent head injuries and concussions (8,14). At the youth level, multiple states — led by Washington State — have enacted legislation that prohibits or limits participation by youth athletes diagnosed with or suspected of having a concussion (29,45). Youth baseball parents and coaches are experiencing a movement aimed at promoting the pitchers’ use of protective helmets, in an effort to prevent head injuries and sport-related con-

Background Definition

The Third International Conference on Concussion in Sport has defined concussion as a complex pathophysiologic process induced by traumatic biomechanical forces (31). Concussion is an entity that can occur not only from direct head trauma, but also from a force transmitted to the head, even if seemingly mild (19,33). Concussion is identified clinically by a myriad of symptoms, as well as functional cognitive disturbance. Typically, a concussion resolves in 7 to 10 d, and current recommendations include at least a 6-d return-to-play protocol following the diagnosis of a concussion (31). Complications resulting from a sport-related concussion, such as postconcussion syndrome and even possibly fatal outcomes, have been described and discussed (24,30). As well, studies have shown an association between late-life cognitive effects, depression, and a history of concussion in retired professional football players (16,17). Unfortunately, there are no true prospective data on the long-term complications of concussion.

Epidemiology and Risk

The U.S. Centers for Disease Control and Prevention (CDC) estimates that between 1.6 and 3.8 million treated and untreated sports-related concussions occur each year, based on estimates of emergency department visits (36). Pellman *et al.* reported a concussion incidence of 0.41 concussions per game in the NFL (39). A 2001 survey by Booher *et al.* reported an incidence of 5.56 concussions per 1,000 athletic exposures in 87 Division I-A football

Department of Family & Community Medicine, The University of Texas Health Science Center at San Antonio, San Antonio, TX

Address for correspondence: Rodolfo R. Navarro, MD, Department of Family & Community Medicine, The University of Texas Health Science Center at San Antonio, Mail Code 7795, 7703 Floyd Curl Drive, San Antonio, TX 78229-3900 (E-mail: navarror2@uthscsa.edu).

1537-890X/1001/27-31

Current Sports Medicine Reports

Copyright © 2011 by the American College of Sports Medicine

programs (6). Tommasone *et al.* reports an incidence of concussion of between 0.18 and 3.6 per 1,000 exposures in high-school athletes (47). There is suggestion from all of these reports that the true incidence of concussion remains underreported. With regards to risk factors, a personal history of having had a previous concussion is a risk factor for having a repeat concussion (18). However, being of female gender, physical fatigue, and a family history of concussions also may be independent risk factors for experiencing concussion (28).

The Concept of Protection

The concept of equipment for the prevention of sport-related concussions, or head injuries in general, certainly is not novel. While helmets have been used since the early 1900s in the NFL, they were not mandatory until 1943. Since then, the materials, designs, and safety standards have undergone revision, and more recent modifications have focused on improving the design to further protect the athlete specifically from concussive impacts (7,26). Biomechanical studies have shown that newer football helmets may reduce the impact forces associated with a sport-related concussion (49). A 2006 unblinded and uncontrolled study suggested that these newer helmet designs might decrease but not prevent the incidence of sport-related concussions in high-school football players (11). Cantu recently opined that, despite biomechanical research showing impact-force reduction in newer football helmet designs, the inherent material design of such football helmets is ideal for preventing high-energy impact forces associated with catastrophic head injuries and less ideal for reducing the lower-impact forces to which concussions typically are related (9). As newer protective equipment for the head, neck, or face becomes available, clinical trials are necessary to assess the actual effectiveness in preventing sport-related concussions.

The Prevention of Concussion Football

For the sport of football, a single 2009 prospective cohort survey by Singh *et al.* attempted to evaluate the effect of a customized mandibular orthotic (CMO) in the prevention of sport-related concussions in high-school football players. The study describes an oral CMO as a customized, laboratory-fabricated appliance for the alignment of the upper and lower jaws, providing spatial correction of the temporomandibular joint (TMJ). Based on biomechanical studies available, the authors posit that correction and stabilization of the TMJ may provide indirect protection of the temporal lobes and thus play a role in the prevention of sport-related concussions. A nonrandomized group of high-school football players presenting for CMO served as the study group. Data were obtained via a patient-completed questionnaire done before to the orthotic fitting and again after three consecutive seasons of using the CMO during football participation. The football players reported a total of 59 Grade I or II concussions having occurred in the 2 yr before using the CMO; only three concussions were reported in the three seasons of play with the CMO. The study reports an odds ratio of 38.33, with sport-related concussion 7.67 times more likely to have occurred in the football players without use of the CMO (46).

The lack of randomization of study participants and the lack of a control group are obvious limitations of this study. Also, the authors note the lack of control in the actual diagnosis of sport-related concussion made by coaching and training staff not involved with the study. The self-reported, survey-based data collecting method also is not ideal. Because of the timing between completions of the questionnaires, 2.4 yr, age and experience level could have had an effect on the final data. Moreover, the large number of players with a previous history of concussion lends to the possibility of self-selection bias; additional self-selection bias could be from more cautious play by a group of players with a history of concussions. As a final point, the authors of the study did not report on the players' compliance with the CMO. Despite the assumption that a mouthguard-type device is required at this level of play, it does not imply that the players used the CMO in the study, certainly affecting the final data and conclusion of the authors. These noted limitations of a preliminary study prohibit any conclusion that CMO use in football participants affects the incidence of sport-related concussion.

Rugby

Two prospective studies recently evaluated the protective effect of headgear on concussion in rugby players. The first was a cohort study by Hollis *et al.* that followed over 3,000 male, nonprofessional rugby players over at least one season. Trained injury recorders, who had no mentioned interaction with the teams' medical staff, collected data regarding mouthguard and headgear use, as well as the main outcome data of concussion, here referred to as mild traumatic brain injury (mTBI). There was an overall incidence of mTBI in the cohort at 7.97 per 1,000 exposures and an overall rate of 9.8% of all players. The incidence of mTBI in players who rarely wore protective headgear was almost twice that of players who reported always wearing headgear. The incidence of mTBI in players who rarely used a mouthpiece was also almost twice the incidence of those who reported always using a mouthpiece. The incidence of mTBI also was noted to be higher in players reporting higher impulsivity scores and in players with less than 3 h·wk⁻¹ of training. In further age group analysis, the data also showed a higher incidence of mTBI in less-experienced players (less than 4 yr playing) and more-experienced players (more than 8 yr playing). The study recommends not only the use of protective headgear in rugby athletes but also the proper management of prior or current mTBI as means to reduce the incidence of mTBI (23).

However, the reporting of mTBI is not ideal in this study, as not all data collectors were trained or specified to have access to the team's medical staff. This may have led to an altered incidence rate of mTBI. The self-reporting of mouthguard and headgear use does not randomize the study interventional and control groups for analysis. Also, the association of concussion with impulsivity raises the possibility of self-selection bias contributing to confounding the final data (43). Finally, in review of the data analysis on mouthguards, the confidence intervals for the two groups have significant overlap, devaluing the findings regarding mouthguards. Unfortunately, no conclusive evidence-based support for or against mouthguard or headgear use as a

protective measure in rugby participants can be made based on this study alone.

McIntosh *et al.* performed a randomized, control trial of 3,686 males, aged 12 to 21 yr, in rugby union football over two seasons. The study aimed to determine a risk reduction in the rate of head injury or concussion over two rugby seasons, in three cohorts of players: those without headgear, those with standard headgear, and those with modified headgear. The modified headgear was created from thicker and denser protective foam than the standard headgear. Individual teams were block-randomized to either the control group or one of the intervention groups. Data were collected via trained primary data collectors who were able to corroborate medical data with the trained medical staff. When comparing the three groups against each other and establishing the nonusers as the reference baseline, there was no significant difference in injury rates for concussions. The overall concussion injury rate as a proportion of all injuries was found to be similar to other studies. Compliance with wearing of the standard or modified headgear was noted to be poor throughout the study and thus could be a major data confounder for the final analysis. The study mentions other limitations, including player position, aggressiveness, and history of head injuries or concussions, as these were not assessed in the study. The issue of the poor compliance was addressed, as it was difficult to mandate the use of headgear or to request players who already used protective headgear to stop using it (32). Despite its limitations, this does present a true randomized study of protective headgear in rugby and does not support the use of standard headgear — or a modified version — for the prevention of concussions.

Soccer

Delaney *et al.* utilized a retrospective, cross-sectional survey of adolescent soccer players to attempt to analyze the association of headgear use, concussion incidence, and risk factors based on self-reported symptoms. The study showed that, compared with players wearing headgear, those players without headgear carried an adjusted relative risk of 2.65 for experiencing concussion. Being female carried almost double the risk of concussion. The majority of players who used headgear were female, had experienced previous concussion, and were more likely to use mouthguards. The survey did acknowledge its own limitations, including the retrospective nature. The definition of a concussion may have been a confounder as well, as almost 50% of the surveyed athletes claimed to have had a concussion, but only 15% of these athletes also claimed to have recognized that they had done so (13). Although the two points raise concern over the validity of the self-reporting of the players' symptoms, they also reinforce the concepts of lack of education and lack of reporting of concussion-like symptoms in athletes. Given the noted limitations of the survey, it would be difficult to extrapolate the results of this study to a more general soccer population.

Field Hockey

Hendrickson *et al.* conducted a prospective, survey-based study of head and facial injuries in collegiate female field hockey players. The study spanned six Division I collegiate

schools and examined head and facial injuries across 2 yr of competition, as reported by the respective field-hockey-certified athletic trainers. Besides a mouthguard, no other protective head or facial equipment was worn uniformly by players. One team was mentioned as providing clear, protective faceshields for use in practice but not games. There were 62 head and facial injuries reported over the 2 yr, with lacerations and contusion/hematoma comprising the top two injury categories. Concussions represented 18% of these injuries, being the third most common injury. Unfortunately, a subgroup analysis on the data concerning injuries and, in particular, sport-related concussions in the athletes who wore faceshields is not provided. However, the article suggests that based on this survey, faceshields may offer a beneficial effect in preventing head injuries, including concussion (21).

Ice Hockey

Asplund *et al.* conducted a systematic review of cohort studies on facial protection in ice hockey and its association with facial and head injuries, including concussions. The studies spanned dates from 1987 through 2007. The review was able to evaluate full facial versus half facial protection in the prevention of facial and head injuries. The review found no significant difference in the comparative rates of concussion incidence, even compared with no facial protection. Based on the reported time to return-to-play, however, the data suggest that full facial protection is associated with a lower severity of concussion when sustained by a player (2).

Discussion

Multiple equipment-based methods for the prevention of sport-related concussion have been proposed, yet the literature discussed here fails to argue overwhelmingly in favor of such a role. No protective equipment was shown to produce a zero-risk incidence for sport-related concussion, and many of the studies were limited by design. The Table outlines the effectiveness of different protective equipment types in their respective sports. CMO provided poor evidence of decreasing the risk of suffering a concussion. Mouthguards showed limited evidence of reducing but not eliminating the risk of sport-related concussion in rugby players. Standard and modified headgear in rugby players, though, showed conflicting data on decreasing the rate of

Table.

Effectiveness of Protective Equipment in Preventing Concussions.

<i>Sport</i>	<i>Equipment Type</i>	<i>Effective?</i>	<i>Highest Level of Evidence</i>
Football	CMO	No	4
Rugby	Mouthguard	No	2
Rugby	Headgear	Inconclusive	2
Soccer	Headgear	No	3
Field hockey	Faceshield	Inconclusive	4
Ice hockey	Faceshield	No	2

CMO = customized mandibular orthotic.

sport-related concussion. The use of headgear in soccer players showed a decreased relative risk according to retrospective survey data. As well, survey data indirectly suggested a possible decreased risk of concussion in field hockey players wearing faceshields in practices. Finally, a systematic review of cohort studies revealed no decreased risk of concussion in ice hockey players using faceshields compared with those not using faceshields.

In addition to the literature presented here, a 2009 systematic review by Benson *et al.* systematically reviewed the prevention of sport-related concussion. These studies included prospective cohort studies, cross-sectional surveys, and randomized, controlled trials from 2002 through 2005. According to the review, there was no evidence that a mouthguard prevented concussions in users compared with nonusers in ice hockey, football, basketball, and rugby. The review also noted that helmet use in skiers, snowboarders, and bicyclists reduced the risk of head injury. None of these particular studies, however, explicitly evaluated for concussion. For both soccer and rodeo, only observational data were available but did suggest a potential protective role for helmet and headgear use (5). The findings of the review are familiar in that no protective equipment was found to prevent sport-related concussions convincingly.

If protective equipment were proven to prevent sport-related concussions, their use likely would increase and even become enforced. However, disparity in attitudes and desires among athletes and coaches contributes to an actual lack of use of protective equipment for the prevention of sport-related concussion. Turbeville *et al.*, using a Web-based anonymous survey of 131 NCAA schools' pole-vaulting coaches, found that while 68% of coaches felt that helmets prevented head injuries, none required their athletes to use them, and only 21% thought that helmets should be required. Despite the disparities, 59% claimed that they would consider requiring helmet use if a helmet was specifically designed for pole vaulting (48). In similar fashion, a 2004 survey of teenagers cited discomfort and lack of need as the main reasons they did not use personal protective equipment, while citing a personal injury or having witnessed an injury in a friend as the primary reasons to begin using personal protective equipment (27).

Despite this disparity, protective equipment should be used, if not mandated, where it has been shown to be effective in reducing injuries, unless proven to be detrimental to the athlete. Helmet use should be mandated in all contact or collision sports where scientific evidence demonstrates a clear safety advantage for the user, and research into improving the design of existing helmets should continue (7,19,26,33,40,44). For sports in which scientific evidence is lacking regarding protective equipment use, athletes should be educated about the potential safety benefits versus risks and should be allowed to make informed decisions. Faceshields and mouthguards should be encouraged, especially where required, as they have proven to reduce orofacial injuries, despite the inability to prevent concussions (2,5,12,25,35).

However, Cantu recently concluded, based on the inherent paradox in football helmet design, "It is unlikely, given the present materials, that helmets will solve the concussion crisis," and proposes guidelines for safer sports (9). It would

be similarly prudent to promote the role of nonequipment-based methods of preventing sport-related concussions. The rules of gameplay should be reviewed constantly and enforced strictly so that risk of injury via violent or illegal actions can be minimized (10,38,50), similar to the elimination of spearing in the NFL (37). Medical staff should be provided with the authority to triage safely and appropriately and manage injured athletes in a nonthreatening or time-limited manner. Proper technique should be encouraged by both medical and coaching staff, as certain maneuvers, such as heading the ball in soccer (41,51), are safe if performed properly. As well, game situation awareness may offer a protective role in preventing sport-related concussions and injuries. For example, proper anticipation of a collision in sports such as ice hockey may reduce the force of impact (34). The continued education of athletic participants at all levels is necessary, and they should be instructed and encouraged to seek medical attention when experiencing a possible concussion or head injury. Finally, the education of amateur and youth coaches and officials should be encouraged and required, as both the CDC Heads Up toolkit (20) and the Athletic Concussion Training using Interactive Video Education (1) have been shown to improve coaches' self-reported knowledge bases and management principles (15,42).

What research has been conducted on the role of sports equipment and sport-related concussion has not proven a protective effect, but these efforts should be lauded as the paradigm of the role of sports medicine in the prevention of injuries. The lack of conclusive data illuminates the idea that much remains undiscovered on this complex and emotional topic. However, a combination of appropriate protective equipment and nonequipment-based protective methods will help create an environment that promotes athletes' safety against sport-related concussion.

References

1. Active: Athletic Concussion Training for Coaches. [Internet] Eugene (OR): Oregon Center for Applied Science; c2009 [cited 2010 Aug 1]. Available from: <http://athleticconcussion.com/>.
2. Asplund C, Bettcher S, Borchers J. Facial protection and head injuries in ice hockey: a systematic review. *Br. J. Sports Med.* 2009; 43(13):993-9.
3. The Associated Press. NFL changes return-to-play rules. [Internet] Bristol (CT): ESPN; 2009, c2009 [modified 2009 Dec 3; cited 2010 Aug 1]. Available from: sports.espn.go.com/nfl/news/story?id=4707604.
4. The Associated Press. NFL to post sternly worded concussion warning poster in lockers rooms. [Internet] Bristol (CT): ESPN; 2010, c2010 [modified 2010 Jul 27; cited 2010 Aug 1]. Available from: sports.espn.go.com/nfl/news/story?id=5412862.
5. Benson BW, Hamilton GM, Meeuwisse WH, McCrory P, Dvorak J. Is protective equipment useful in preventing concussion? A systematic review of the literature. *Br. J. Sports Med.* 2009; 43 (Suppl. 1):i56-67.
6. Boher MA, Wisniewski J, Smith BW, Sigurdsson A. Comparison of reporting systems to determine concussion incidence in NCAA Division I collegiate football. *Clin. J. Sport Med.* 2003; 13(2):93-5.
7. Brolinson PG, Manoogian S, McNeely D, et al. Analysis of linear head accelerations from collegiate football impacts. *Curr. Sports Med. Rep.* 2006; 5(1):23-8.
8. Brown AK. Helmet use on the rise in rodeo. [Internet] McLean (VA): USA TODAY; 2008 Jan, c2008 [cited 2010 Aug 1]. Available from: http://www.usatoday.com/news/nation/2008-01-29-2401691528_x.htm.
9. Cantu RC. Active voice: is helmet design the answer to concussion in collision sports? [Internet]. *Sports Medicine Bulletin*. Indianapolis (IN): American College of Sports Medicine; c2010 [cited 2010 Nov 8]. Available from: <http://multibriefs.com/briefs/acsm/ACSM100510.php#6>.

10. Cantu RC, Mueller FO. The prevention of catastrophic head and spine injuries in high school and college sports. *Br. J. Sports Med.* 2009; 43(13):981–6.
11. Collins M, Lovell MR, Iverson GL, Ide T, Maroon J. Examining concussion rates and return to play in high school football players wearing newer helmet technology: a three-year prospective cohort study. *Neurosurgery.* 2006; 58(2):275–86.
12. dela Cruz GG, Knapik JJ, Birk MG. Evaluation of mouthguards for the prevention of orofacial injuries during United States Army basic military training. *Dent. Traumatol.* 2008; 24(1):86–90.
13. Delaney JS, Al-Kashmiri A, Drummond R, Correa JA. The effect of protective headgear on head injuries and concussions in adolescent football (soccer) players. *Br. J. Sports Med.* 2008; 42(2):110–5.
14. Downey DJ. Rodeo injuries and prevention. *Curr. Sports Med. Re.* 2007; 6(5):328–32.
15. Glang A, Koester MC, Beaver SV, Clay JE, McLaughlin KA. Online training in sports concussion for youth sports coaches. *Int. J. Sports Sci. Coach.* 2010; 5(1):1–12.
16. Guskiewicz KM, Marshall SW, Bailes J, et al. Association between recurrent concussion and late-life cognitive impairment in retired professional players. *Neurosurgery.* 2005; 59(4):719–26.
17. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med. Sci. Sports Exerc.* 2007; 39(6):903–9.
18. Guskiewicz KM, McCrea M, Marshall SW, et al. Cumulative effects associated with recurrent concussion in collegiate football players: the NCAA Concussion Study. *JAMA.* 2003; 290(19):2549–55.
19. Guskiewicz KM, Mihalik JP, Shankar V, et al. Measurement of head impacts in collegiate football players: a relationship between head impact biomechanics and acute clinical outcome after concussion. *Neurosurgery.* 2007; 61(6):1244–52.
20. Heads Up: Concussion in Youth Sports [Internet]. Atlanta (GA): Centers for Disease Control and Prevention (US); [updated 2009 Dec 8; cited 2010 Aug 1]. Available from: <http://www.cdc.gov/concussion/HeadsUp/youth.html>.
21. Hendrickson CD, Hill K, Carpenter JE. Injuries to the head and face in women's collegiate field hockey. *Clin. J. Sport Med.* 2008; 18(5):399–402.
22. Henson S. Pitcher head injuries to trigger cry for protection [Internet]. Sunnyvale (CA): Yahoo! Inc; 2010, c2010 [cited 2010 Aug 1]. Available from: <http://sports.yahoo.com/mlb/news?slug=sh-headinjuries052710>.
23. Hollis SJ, Stevenson MR, McIntosh AS, et al. Incidence, risk, and protective factors of mild traumatic brain injury in a cohort of Australian nonprofessional male rugby players. *Am. J. Sports Med.* 2009; 37(12):2328–33.
24. Jotwani V, Harmon KG. Postconcussion syndrome in athletes. *Curr. Sports Med. Rep.* 2010; 9(1):21–6.
25. Knapik JJ, Marshall SW, Lee RB, et al. Mouthguards in sport activities: history, physical properties and injury prevention effectiveness. *Sports Med.* 2007; 37(2):117–44.
26. Krauss MD. Equipment innovations and rules changes in sports. *Curr. Sports Med. Rep.* 2004; 3(5):272–6.
27. Kroncke EL, Niedfelt MW, Young CC. Use of protective equipment by adolescents in inline skating, skateboarding, and snowboarding. *Clin. J. Sport Med.* 2008; 18(1):38–43.
28. Kutcher JS, Eckner JT. At-risk populations in sports-related concussion. *Curr. Sports Med. Rep.* 2010; 9(1):16–20.
29. The Lystedt Law. [Internet] Washington: Brain Injury Association of Washington; c1997, 2009. [cited 2010 Aug 1]. Available from: <http://www.biawa.org/lystedt.htm>.
30. McCrory P. Does second impact syndrome exist? *Clin. J. Sport Med.* 2001; 11(3):144–9.
31. McCrory P, Meeuwisse W, Johnston K, et al. Consensus statement on concussion in sport — the 3rd international conference on concussion in sport held in Zurich, November 2008. *PMR.* 2009; 1(5):406–20.
32. McIntosh AS, McCrory P, Finch CF, et al. Does padded headgear prevent head injury in rugby union football? *Med. Sci. Sports Exerc.* 2009; 41(2):306–13.
33. Mihalik JP, Bell DR, Marshall SW, Guskiewicz KM. Measurement of head impacts in collegiate football players: an investigation of positional and event-type differences. *Neurosurgery.* 2007; 61(6):1229–35.
34. Mihalik JP, Blackburn JT, Greenwald RM, et al. Collision type and player anticipation affect head impact severity among youth ice hockey players. *Pediatrics.* 2010; 125(6):e1394–401.
35. Mihalik JP, McCaffrey MA, Rivera EM, et al. Effectiveness of mouthguards in reducing neurocognitive deficits following sports-related cerebral concussion. *Dent. Traumatol.* 2007; 23(1):14–20.
36. MMWR Weekly Report. [Internet] Atlanta (GA): Centers for Disease Control and Prevention. 56(29):733–737, 2007 Jul 27 [cited 2010 Aug 1]. Available from: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5629a2.htm>.
37. Mueller FO. Sports related head and brain trauma. *N. C. Med. C.* 2001; 62(6):368–72.
38. Patel DR, Reddy V. Sport-related concussion in adolescents. *Pediatr. Clin. North. Am.* 2010; 57(3):649–70.
39. 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):81–94.
40. Powell JW, Dompier TP. The role of the helmet in the prevention of traumatic brain injuries. *Curr. Sports Med. Rep.* 2004; 3(1):20–4.
41. Putukian M. Heading in soccer: is it safe? *Curr. Sports Med. Rep.* 2004; 3(1):9–14.
42. Sarmiento K, Mitchko J, Klein C, Wong S. Evaluation of the Centers for Disease Control and Prevention's concussion initiative for high school coaches: "Heads Up: Concussion in High School Sports." *J. Sch. Health.* 2010; 80(3):112–8.
43. Schick D. Risk of mild traumatic brain injury in rugby players. *Clin. J. Sport Med.* 2010; 20(4):330–1.
44. Schwarz A. Helmet design absorbs shock in a new way. [Internet] New York (NY). *The New York Times*; 2007, c2007. [cited 2010 Aug 1]. Available from: <http://www.nytimes.com/2007/10/27/sports/football/27helmets.html?pagewanted=1&r=2>.
45. Schwarz A. States taking the lead addressing concussions in youth sports. [Internet] New York (NY). *The New York Times*; 2010, c2010. [cited 2010 Aug 1]. Available from: <http://www.nytimes.com/2010/01/31/sports/31concussions.html>.
46. Singh GD, Maher GJ, Padilla RR. Customized mandibular orthotics in the prevention of concussion/mild traumatic brain injury in football players: a preliminary study. *Dent. Traumatol.* 2009; 25(5):515–21.
47. Tommasone BA, Valovich McLeod TC. Contact sport concussion incidence. *J. Athl. Train.* 2006; 41(4):470–2.
48. Turbeville SD, Cowan LD, Pasque CB, Williams T. Acceptance of helmet use among national collegiate athletic association pole-vaulting coaches. *Int. J. Sports Sci. Coach.* 2007; 2(2):191–6.
49. Viano DC, Pellman EJ, Withnall C, Shewchenko N. Concussion in professional football: performance of newer helmets in reconstructed game impacts — Part 13. *Neurosurgery.* 2006; 59(3):591–606.
50. Warsh JM, Constantin SA, Howard A, Macpherson A. A systematic review of the association between body checking and injury in youth ice hockey. *Clin. J. Sport. Med.* 2009; 19(2):134–44.
51. Zetterberg H, Jonsson M, Rasulzada A, et al. No neurochemical evidence for brain injury caused by heading in soccer. *Br. J. Sports Med.* 2007; 41(9):574–7.