Effectiveness of mouthguards in reducing neurocognitive deficits following sports-related cerebral concussion

Mihalik JP, McCaffrey MA, Rivera EM, Pardini JE, Guskiewicz KM, Collins MW, Lovell MR. Effectiveness of mouthguards in reducing neurocognitive deficits following sports-related cerebral concussion.

Abstract – Although it is widely accepted that mouthguards decrease the incidence of dental injuries, there is a controversy among sports medicine professionals as to the effectiveness of mouthguards in decreasing the incidence or severity of sports-related cerebral concussion (SRCC). While some experimental data suggest that this may be the case, there exist a number of reports suggesting that mouthguards do not serve this purpose. These conclusions have been drawn, however, without actually measuring the extent of neurocognitive dysfunction in athletes following sports-related concussion. The purpose of this study was to determine whether mouthguard use reduces the neurocognitive and symptomatic impairments that follow an injurious episode of SRCC. Preseason baseline data were collected as part of an ongoing clinical program that uses a computerized neurocognitive test to assess various faculties of brain function and symptoms reported at the time of testing. Follow-up testing from 180 student-athletes who had sustained an SRCC was analyzed for the purpose of this study. These athletes were separated into one of two groups: those who reported using mouthguards and those who did not. Neurocognitive testing was accomplished using the Immediate Post-Concussion and Assessment Test (ImPACT). Results suggest that neurocognitive deficits at the time of the athletes' first follow-up assessment did not differ between mouthguard users and non-users, suggesting that mouthguard use does little to reduce the severity of neurocognitive dysfunction and onset of symptoms following sports-related head trauma. However, an interesting finding in this study was that athletes experienced significantly lower neurocognitive test scores and reported higher symptom scores following SRCC regardless of mouthguard use. This emphasizes a thorough clinical evaluation of athletes that have sustained an SRCC. Although it was found in this study that mouthguard use does not decrease the severity of concussion, it is important to note that the use of mouthguards is paramount in reducing maxillofacial and dental trauma and their use should continue to be mandated by athletic associations and supported by all dental and sports medicine professionals.

Jason P. Mihalik[1,2,3], Meghan A. McCaffrey[1,3], Eric M. Rivera[4], Jamie E. Pardini[5], Kevin M. Guskiewicz[1,2,3], Michael W. Collins[5], Mark R. Lovell[5]

[1]Sports Medicine Research Laboratory; [2]Curriculum in Human Movement Science; [3]Department of Exercise and Sport Science; [4]Department of Endodontics, The University of North Carolina at Chapel Hill, Chapel Hill, NC; [5]Sports Medicine Concussion Program, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Key words: mild traumatic brain injury; high school athlete; concussion recovery; oral injury

Jason P. Mihalik MS, CAT(C), ATC, Sports Medicine Research Laboratory, University of North Carolina at Chapel Hill, CB#8700, Fetzer Gymnasium South Road Chapel Hill, NC 27599, USA
Tel.: +1-919-962-7187
Fax: +1-919-962-0489
e-mail: jasonm@unc.edu

Accepted 18 January, 2006

Because of the impact that sports-related cerebral concussion (SRCC) has had on several high-profile professional athletes in recent years, the management of this condition continues to be a topic of high interest for medical professionals that are charged with the care of athletes. It has been estimated that there are over 300 000 SRCCs each year (1). Injuries of this nature more commonly occur in American football, soccer, and ice hockey. A recent study by Delaney found concussion injury rates (for every 10 000 participants) to be as high as 5.20, 3.10, and 4.90 in these three sports respectively (2). In a study that investigated cerebral concussion incidence among 50 NCAA Division I basketball programs, an incidence rate of 5.22 (for every 10 000 participants) was reported (3). With the prevalence of SRCCs seemingly on the rise, and the detriment it may have on athletes of all ages, there is a heightened interest in the prevention, recognition, and treatment of SRCC (2). There have been 19 grading scales and return-to-play guidelines published in the literature. However, these are anecdotal and lack any empirical evidence to substantiate any one as superior. It is for this reason that the management of SRCC remains one of the most clinically challenging areas of sports medicine. In an attempt to increase athlete safety and decrease the effects of concussion, many sport-governing bodies have mandated the use of protective equipment (4). One such rule modification is the mandated use of mouthguards in football and ice hockey to reduce dental and maxillofacial injuries (5). It has long been argued that a mouthguard may also prevent and reduce the severity of SRCC sustained during athletic competition; however, there have been contradicting reports in the literature in an attempt to justify their use for this purpose (3, 6–8).

The literature illustrates the effectiveness of mouthguard use for injury prevention in athletics. Previously published case reports convey that athletes prone to concussions reported a decline in symptoms while wearing a mouthguard (6). Mouthguards have also been studied in the context of biomechanics. In one such study, there was evidence that mouthguards decreased intracranial pressure in a human cadaver following a number of inflicted head impacts (7). Mouthguard use, although mandatory in many sports, has also served to increase athlete awareness of a mouthguard's ability to prevent injuries. A recent study of 127 NCAA collegiate ice hockey teams found that 93% of the athletes wore a mouthguard because he or she believed it was vital in the prevention of injuries, including SRCC (5).

In contrast, the role of mouthguards has been brought into question as sports medicine professionals strive to prevent SRCC. A study among NCAA basketball players revealed that there was no difference in the incidence of concussion in athletes who did wear mouthguards compared with those athletes who did not (3). A study of South African rugby players revealed no notable difference in the prevalence of cerebral concussion between mouthguard users and non-users (9). Wisniewski et al. found no statistical difference between the types of mouthguard (custom-made vs non-custom-made) used in NCAA football players and the incidence of SRCC (8). In addition, the type of mouthguard used did not play a significant role in the grade of concussion sustained by the football players (8).

To date, no study has specifically examined the role of mouthguard use in reducing measurable and objective neurocognitive deficits following SRCC. The purpose of this study was to determine whether mouthguard use at the time of injury reduces the neurocognitive and symptomatic impairments that follow an injurious episode of SRCC.

Methods

Participants

There were originally 353 athletes in our injury database. All subjects who had a history of learning disability, special education, speech therapy, or attention deficit disorder were excluded from this study. Furthermore, all athletes with any history of alcohol or drug abuse were also excluded from the study. We also retained only those athletes for whom complete preseason baseline and follow-up testing was present; this consisted of 180 concussed athletes (age = 16.51 ± 3.02 years). The sample consisted of 152 males and 28 females. Subjects were separated into one of two groups based on mouthguard use at the time of his or her injury: mouthguard (MG) group and non-MG group. All concussed participants were evaluated through a concussion program at a university medical center. This ongoing clinical program implements computerized testing to assess neurocognitive and symptom impairments, and assists team medical staff in making return-to-play decisions following the occurrence of SRCC. Athletes were not financially compensated for participation in the program.

Baseline data collection was completed for subjects enrolled in this study. Baseline data were collected during the off-season (i.e. prior to preseason contact drills) and, as a result, prior to any cerebral concussions assessed in this study. At the baseline session, the following self-reported data were collected: age, native language, years of completed education, history of diagnosed learning disability, and history of concussion. A standardized concussion history questionnaire contained within the Immediate Post-Concussion Assessment and

Cognitive Test (ImPACT) battery was completed by each athlete under the supervision of the test administrator. This questionnaire is structured to gather information regarding concussion history and a description of these injuries including the presence of confusion, loss of consciousness, anterograde amnesia (memory loss after the hit), retrograde amnesia (memory loss prior to the hit), and results of neuroimaging procedures (if any). The athletes also completed the neurocognitive testing portion of the ImPACT at this time.

Protocol and outcome measures

The university's Institutional Review Board committee granted approval for research with human subjects. Administration of the ImPACT computerized neuropsychological battery (10) was supervised by a team of clinical neuropsychologists, certified athletic trainers, or physicians, who were thoroughly trained in the administration of the measures. The ImPACT is administered both during preseason baseline testing as well as with any follow-up assessments. Training was completed at each site through a half-day seminar presented by two of the authors (MWC and MRL). All subtests were administered in a standardized manner and the test was automatically computer scored. As a result, there was no variation in administration or scoring technique between participating sites.

The ImPACT is a computer-administered neuropsychological test battery that consists of seven individual test modules that measure aspects of cognitive functioning including attention, memory, reaction time, and information processing speed. The verbal and visual memory composite indices, reaction time composite, visual motor speed composite, and total symptom scores were included in this study to compare the neurocognitive impairments between cerebrally concussed athletes who used a mouthgaurd and those who did not. A thorough description of the ImPACT battery and rationale for the development of the individual tests has been described in detail previously (10). The validity and reliability of the ImPACT has also been previously reported (11–15).

A summary of the individual test modules that comprise the ImPACT is provided in Table 1. The ImPACT is designed to minimize practice effects by randomization of the presentation of the test modules. With the exception of the recognition word memory test (which utilizes five different but equivalent word lists) and design memory test (which utilizes five different but equivalent design lists), presentation of all stimuli is varied automatically for each examination.

Table 1. ImPACT neurocognitive test modules[a]

Test module	Cognitive processes measured
Word memory	Verbal recognition and delayed memory
Design memory	Visual recognition and delayed memory
Xs and Os	Visual working memory and visual processing speed
Symbol matching	Visual processing speed, learning, and memory
Color match	Reaction time and impulse control/inhibition
Three letters	Working memory and visual-motor response speed

[a]Results from these tests are computed into overall memory, reaction time, and visual motor speed composite scores.

The ImPACT also yields a Post-Concussion Symptom Scale (PCSS) that is now being utilized throughout both amateur and professional sports (16). This Likert scale consists of 22 symptoms commonly associated with concussion (e.g. headache, dizziness, nausea, sleep disturbance) that are graded from 0 (asymptomatic) to 6 (severely symptomatic). All the athletes were required to provide a self-report of his or her symptoms through the PCSS which included both cognitive (e.g. attention deficit, perceived memory dysfunction) as well as non-cognitive symptoms (e.g. headache, nausea, dizziness, sleep disturbance, emotional changes, and photophobia). These symptoms are identified in Table 2.

Data analysis

One-way analyses of variance (ANOVA) were performed on the data to assess the research question of a time and mouthguard interaction with group (MG or non-MG) as the between-group factor and postinjury outcome measure (verbal memory, visual memory, visual motor speed, reaction time, and symptom score) as the within-group factor. The level of significance was set *a priori* ($\alpha = 0.05$). To compare postinjury and preseason baseline scores within the individual groups, change index scores were computed by subtracting postinjury composite scores from preseason baseline results. Standardized *t*-tests were performed on these change indices within each of the two groups. The *t*-tests compared

Table 2. Symptoms rated in the Post-Concussion Symptom Scale (16)[a]

Headache	Sensitivity to light
Nausea	Sensitivity to noise
Emesis	Increased sadness
Balance problems	Nervousness
Dizziness	Feeling more emotional
Fatigue	Numbness or tingling
Trouble falling asleep	Feeling slowed down
Sleeping more than usual	Sensation of being "in a fog"
Sleeping less than usual	Difficulty with concentration
Drowsiness	Difficulty with memory
Irritability	Visual problem

[a]Each item is graded from 0 (asymptomatic) to 6 (severely symptomatic).

Table 3. Demographic data for MG and non-MG athletes

	MG group	Non-MG group	Total Sample
Total subjects	121 (67.2)	59 (32.8)	180 (100)
Mean age (years)	16.63 (SD 2.61)	16.26 (SD 3.74)	16.51 (SD 3.02)
Sex			
Male	115 (95.0)	37 (67.7)	152 (84.4)
Female	6 (5.0)	22 (37.3)	28 (15.6)
Sport			
Football	111 (91.7)	20 (33.9)	131 (72.8)
Soccer	4 (3.3)	13 (22.0)	17 (9.4)
Basketball	2 (1.7)	9 (15.3)	11 (6.1)
Other	4 (3.3)	17 (28.8)	21 (11.7)
History of previous concussion			
Yes	43 (35.5)	25 (42.4)	68 (37.8)
No	78 (64.5)	34 (57.6)	112 (62.2)

Values in parentheses are given in percentage.

the magnitude of the change index scores to the hypothetical non-injured difference score of 0.

Results

A breakdown of the sample of injured athletes by age, sex, sport, and history of concussion is provided in Table 3. Previous history of concussions in athletes in the MG group and the non-MG group did not significantly differ ($\chi^2 = 0.788$, $P = 0.375$). The mean time from injury to the first follow-up evaluation for all the participants was 3.27 (±5.97) days; this did not differ significantly between groups ($F = 0.18$, $P = 0.674$).

Comparisons between MG and non-MG athletes

ImPACT postinjury neurocognitive composite and symptom scores (and standard deviations) for the MG and non-MG groups are provided in Table 4.

Neurocognitive performance and Post-Concussion Symptom Scale: postinjury

There were no significant differences between groups for verbal memory scores ($F = 0.177$, $P = 0.675$). Differences in visual memory scores between groups were not statistically significant ($F = 1.617$, $P = 0.205$). Differences were not observed between groups for visual motor speed scores ($F = 0.372$, $P = 0.543$). Significant differences between groups were not noted for reaction time scores ($F = 0.259$, $P = 0.612$). Symptom status did not differ between groups ($F = 0.655$, $P = 0.42$); i.e. the non-MG group did not self-report a significantly higher symptom score than the MG group.

Comparisons within MG and non-MG athletes

ImPACT baseline neurocognitive composite and symptom scores (and standard deviations) for the MG and non-MG groups are also provided in Table 4.

Neurocognitive performance and Post-Concussion Symptom Scale: postinjury vs baseline

There were significant declines within the MG ($t = 8.05$, $P < 0.001$) and non-MG ($t = 5.56$, $P < 0.001$) groups in postinjury verbal memory test scores when compared with those obtained during baseline testing. An analysis of visual memory scores revealed a significant departure from baseline in the MG group ($t = 2.69$, $P = 0.008$). Although there was a mean decrease in visual memory test scores in the non-MG group, this observation was not statistically significant ($t = 1.85$, $P = 0.069$). Visual motor processing speed decreased in both the MG ($t = 3.34$, $P = 0.001$) and non-MG ($t = 3.24$, $P = 0.002$) groups. An increase in reaction time was found in the MG ($t = 5.86$, $P < 0.001$) and non-MG ($t = 3.25$, $P = 0.002$) groups. We observed a statistically significant increase in symptom status reporting following injury in both groups. The non-MG group reported the largest mean increase in symptom status scores ($t = 7.02$, $P < 0.001$) compared with their baseline symptom reports. The MG group, however, also reported a statistically higher symptom status score following injury when compared with their preseason baseline score ($t = 10.47$, $P < 0.001$).

Table 4. Preseason baseline and postinjury neurocognitive performance and symptom status for MG and non-MG athletes

	MG group		Non-MG group	
Variable	Baseline	Postinjury	Baseline	Postinjury
Verbal memory	85.68 (8.64)	76.33 (13.42)*	86.69 (8.52)	77.24 (13.91)*
Visual memory	73.78 (13.41)	65.57 (14.17)*	75.10 (10.33)	62.76 (12.72)
Reaction time	0.558 (0.069)	0.633 (0.143)*	0.594 (0.095)	0.643 (0.109)*
Visual motor speed	35.87 (6.87)	33.28 (9.21)*	35.31 (6.16)	32.43 (7.73)*
Symptom score	7.86 (7.64)	24.74 (18.62)*	9.54 (11.94)	27.36 (21.92)*

Higher scores indicate better functioning for verbal memory, visual memory, and visual motor speed. Lower scores indicate better functioning for reaction time and symptom scores. Significant difference (*$P < 0.01$) was found between baseline score and postinjury score.

Discussion

Overall, results of the study suggest that mouthguard use does not result in any observable differences in neurocognitive performance following concussion. The entire sample showed a significant decline in neurocognitive performance from preseason baseline measures; there was also a concomitant increase in the severity of self-reported symptoms following an SRCC. This finding is consistent with previously reported studies (14, 17–25). Observed declines in neurocognitive and symptom status following SRCC further emphasizes the need to fully and serially follow the recovery of an athlete until he or she has safely returned to play. Our results support a detailed assessment of symptoms not only at the time of injury, but also in the follow-up clinical assessment of the injured athlete, regardless of mouthguard use. Based on our results, SRCC is clearly related to increased cognitive impairments regardless of mouthguard use. Therefore, it is critical that any athlete sustaining a concussion be followed up not only through symptom assessment but also through cognitive assessment, as symptoms and neurocognitive function do not always recover at the same rate (16, 26).

It should be noted that this study did not discriminate between mouthguard types. Future studies should categorize MG users to those that use the three main types of mouthguards: generic stock, boil-and-bite, and custom made (27). The generic stock type of mouthguard is a basic U-shaped piece of rubber which fits loosely over the teeth. Because of its low cost the boil-and-bite mouthguard is the most commonly used (28). The boil-and-bite mouthguard is a thermoplastic material that is heated and formed to the athlete's mouth and remains in that form once it has cooled. The custom-made mouthguard is an involved process, usually requiring the expertise of a dental professional. For this reason, it is often not the mouthguard of choice for athletic programs that have to contend with restricted budgets (e.g. public high school football programs). A model is created by pouring stone into an impression of the athlete's upper jaw made by a licensed dentist. The stone is allowed to set and a model is then created. A thermoplastic material, typically ethylene vinyl acetate, is heated and vacuum-fitted to the mold (8). Although this type of custom-fabricated mouthguard is most comfortable for the athlete, it is also more costly than other types of mouthguards and requires the time of several dental and medical professionals throughout the process. We typically see this type of mouthguard in collegiate and professional settings because of the increased costs of manufacturing the dental mold. Future studies should also differentiate MG types by the thickness of the material. The thickness of the mouthguards produced varies between 3 and 5 mm for all types (29). In the context of preventing SRCC, it is thought that the thickness of the mouthguard repositions the condyles of the temporomandibular joint, resulting in a reduction of the force transmitted to the occiput (30).

Although the current study did not identify the effectiveness that mouthguard use has in reducing the severity of SRCC, it is difficult to question its ability in reducing dental and maxillofacial injuries. For example, one study suggested that the highest incidence of dental injuries is found among basketball and soccer athletes between the ages of 15 and 17 years (31). Despite the effectiveness of protective mouthguards in reducing traumatic dental injuries during sports participation, many athletes still do not choose to use them. This is apparent in the dental and sports medicine literature where there are a large number of published case reports describing facial injuries in amateur athletes. For example, a recently published case reporting extensive maxillofacial fractures and dental trauma in a high school soccer player describes the importance of mouthguard use in reducing the extent of such injuries (32). With regard to this and other cases involving maxillofacial trauma, one must consider the role that preventive measures may have had in reducing the severity of injuries. For example, the use of mouthguards has been shown to be an effective method of decreasing the incidence of mouth and tooth injuries during sports and should be encouraged in players of all ages, particularly those who participate in contact sports (33). As stated earlier in this current study, the use of mouthguards has been mandated in a number of sports, including American football and rugby. In soccer, given the propensity for injuries around the goal, it has been suggested that goalkeepers, in particular, be strongly encouraged to wear protective mouthguards (34).

The preceding discussion is further emphasized by the results presented in this study. Twenty of our injured athletes reported not having used a mouthguard at the time of their injury while playing football. Table 3 illustrates very nicely this concern of many sports medicine professionals and regulation policy makers. Football has mandated the use of mouthguards (5), and not using a mouthguard results in a procedural penalty for the offending team. This further emphasizes the importance of educating coaches and players about the potential benefits of using protective mouthguards. One study surveying participants in a number of different sports including soccer reported that only 26.8% of athletes were aware that the use of protective devices, such as mouthguards, was even an option. This same study also showed that, ultimately, only 2.4% of these athletes actually used a protective device during their activity (31). Given the effectiveness of mouthguards in preventing dental and maxillofacial injuries, these low numbers are staggering and should be of immediate concern for dental professionals involved in any area of sports medicine.

Given that the findings of this current study appear to contradict existing anecdotal accounts of the effectiveness of mouthguard use in reducing severity of concussive injury, future studies should also examine how mouthguard use affects an athlete's neurocognitive function following sports-related head trauma in the context of impact location. It seems intuitive that a mouthguard would have little to do in preventing neurocognitive decline if an athlete sustained an impact to the posterior aspect of the head. However, an impact directed to the head through the facemask in helmeted sports or direct impact with the face in sports not requiring facial protection, may provide a better understanding of the effects that mouthguard use may have on reducing neurocognitive impairments following SRCC.

This study was limited by a relatively small sample size as only the records of those athletes who had completed preseason baseline testing were retained for the purpose of this study. Also, concussed athletes were classified into one of two groups based on the medical professional's evaluation of mouthguard use. This was often self-reported by the athlete and his or her parent during clinical follow up. Finally, only the initial follow-up test scores were used for the purpose of this study. Although it may be argued that the mean time in days of the first follow-up assessment was just over 3 days, this is clinically relevant as it is not uncommon for many amateur football players injured on a Friday afternoon game to be followed up with neuropsychologists on the ensuing Monday. It will be useful for future studies to perform longer term follow up in these athletes to document recovery of neurocognitive deficits and to further examine the potential effectiveness of mouthguard use in preventing observable neurocognitive decline in athletes that have sustained an SRCC. Furthermore, cerebral concussion should not be confused with a dental (tooth) concussion; the latter is defined as an injury to the tooth-supporting structure without abnormal loosening or displacement of the tooth. Finally, previous reports have suggested that athletes with a prior history of learning disabilities results in a higher likelihood of sustaining a cerebral concussion, followed by poorer neurocognitive performance following SRCC (18). It was for this reason that athletes in our sample with a history of learning disabilities and other influencing conditions (i.e. special education and substance abuse) were excluded from our analyses.

Conclusion

This study investigated whether mouthguard use at the time of injury reduces the neurocognitive and symptomatic impairments that follow an injurious episode of SRCC. The findings of this study contradicted anecdotal accounts, revealing no observable differences in deficits between athletes who used a mouthguard and those who did not. Another observation was that regardless of mouthguard use, the athletes exhibited significant decreases from preseason baseline neurocognitive measures, further emphasizing the importance of properly evaluating and managing sports-related head injuries. Although the effectiveness of mouthguard use in reducing neurocognitive deficits needs to be further investigated, mouthguards have been shown to be highly effective in reducing dental and facial trauma and should continue to be worn as a preventative measure in this regard.

References

1. Centers for Disease Control and Prevention. Sports-related recurrent brain injuries – United States. MMWR – Morbidity and Mortality Weekly Report 1997;46:224–7.
2. 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;14:80–7.
3. Labella CR, Smith BW, Sigurdsson A. Effect of mouthguards on dental injuries and concussions in college basketball. Med Sci Sports Exerc 2002;34:41–4.
4. Guskiewicz KM, Bruce SL, Cantu RC et al. National Athletic Trainers' Association Position Statement: management of sport-related concussion. J Athl Train 2004;39:280–97.
5. Hawn KL, Visser MF, Sexton PJ. Enforcement of mouthguard use and athlete compliance in national collegiate athletic association men's collegiate ice hockey competition. J Athl Train 2002;37:204–8.
6. Stenger JM, Lawton EA, Wright JM, Ricketts J. Mouthguards: protection against shock to head, neck, and teeth. J Am Dent Assoc 1964;69:273–81.
7. Hickey JC, Morris AL, Carlson LD, Seward TE. The relation of mouth protectors to cranial pressure and deformation. J Am Dent Assoc 1967;74:735–40.
8. Wisniewski JF, Guskiewicz K, Trope M, Sigurdsson A. Incidence of cerebral concussions associated with type of mouthguard used in college football. Dent Traumatol 2004;20:143–9.
9. Blignaut JB, Carstens IL, Lombard CJ. Injuries sustained in rugby by wearers and non-wearers of mouthguards. Br J Sports Med 1987;21:5–7.
10. Maroon JC, Lovell MR, Norwig J, Podell K, Powell JW, Hartl R. Cerebral concussion in athletes: evaluation and neuropsychological testing. Neurosurgery 2000;47:659–69; discussion 669–72.
11. Iverson GL, Gaetz M, Lovell MR, Collins MW. Relation between subjective fogginess and neuropsychological testing following concussion. J Int Neuropsychol Soc 2004;10:904–6.

12. Iverson GL, Gaetz M, Lovell MR, Collins MW. Cumulative effects of concussion in amateur athletes. Brain Inj 2004;18:433–43.
13. Iverson GL, Lovell MR, Collins MW. Interpreting change on ImPACT following sport concussion. Clin Neuropsychol 2003;17:460–7.
14. Lovell MR, Collins MW, Iverson GL et al. Recovery from mild concussion in high school athletes. J Neurosurg 2003;98:296–301.
15. Lovell MR, Collins MW, Iverson GL, Johnston KM, Bradley JP. Grade 1 or "ding" concussions in high school athletes. Am J Sports Med 2004;32:47–54.
16. Lovell MR, Collins MW. Neuropsychological assessment of the college football player. J Head Trauma Rehabil 1998;13:9–26.
17. Collins MW, Lovell MR, Iverson GL, Cantu RC, Maroon JC, Field M. Cumulative effects of concussion in high school athletes. Neurosurgery 2002;51:1175–9; discussion 1180–1.
18. Collins MW, Grindel SH, Lovell MR et al. Relationship between concussion and neuropsychological performance in college football players. JAMA 1999;282:964–70.
19. Collins MW, Iverson GL, Lovell MR, McKeag DB, Norwig J, Maroon J. On-field predictors of neuropsychological and symptom deficit following sports-related concussion. Clin J Sport Med 2003;13:222–9.
20. Collins MW, Field M, Lovell MR et al. Relationship between postconcussion headache and neuropsychological test performance in high school athletes. Am J Sports Med 2003;31:168–73.
21. Field M, Collins MW, Lovell MR, Maroon J. Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. J Pediatr 2003;142:546–53.
22. Guskiewicz KM, Ross SE, Marshall SW. Postural stability and neuropsychological deficits after concussion in collegiate athletes. J Athl Train 2001;36:263–73.
23. McCrea M, Guskiewicz KM, Marshall SW et al. Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. JAMA 2003;290:2556–63.
24. Guskiewicz KM, McCrea M, Marshall SW et al. Cumulative effects associated with recurrent concussion in collegiate football players: the NCAA Concussion Study. JAMA 2003;290:2549–55.
25. Mihalik JP, Stump JE, Collins MW, Lovell MR, Field M, Maroon JC. Posttraumatic migraine characteristics in athletes following sports-related concussion. J Neurosurg 2005;102:850–5.
26. Mittenberg W, Strauman S. Diagnosis of mild head injury and the postconcussion syndrome. J Head Trauma Rehabil 2000;15:783–91.
27. Woodmansey KF. Athletic mouth guards prevent orofacial injuries: a review. Gen Dent 1999;47:64–9 quiz:70–1
28. Padilla R, Dorney B, Balikov S. Prevention of oral injuries. J Calif Dent Assoc 1996;24:30–6.
29. Winters JE Sr. Commentary: role of properly fitted mouthguards in prevention of sport-related concussion. J Athl Train 2001;36:339–41.
30. Kerr L. Dental problems in athletes. Clin Sports Med 1983;2:115–22.
31. Levin L, Friedlander LD, Geiger SB. Dental and oral trauma and mouthguard use during sport activities in Israel. Dent Traumatol 2003;19:237–42.
32. Mihalik JP, Myers JB, Sell TC, Anish EJ. Maxillofacial fractures and dental trauma in a high school soccer goalkeeper: a case report. J Athl Train 2005;40:116–9.
33. Jones NP. Orbital blowout fractures in sport. Br J Sports Med 1994;28:272–5.
34. Sullivan JA, Gross RH, Grana WA, Garcia-Moral CA. Evaluation of injuries in youth soccer. Am J Sports Med 1980;8:325–7.