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The Efficacy of Soccer Headgear

Steven P. Broglio; Yan-Ying Ju; Michael D. Broglio; Timothy C. Sell

University of Pittsburgh, Pittsburgh, PA

Steven P. Broglio, MS, ATC, contributed to conception and design; acquisition and analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Yan-Ying Ju, PhD, PT, ATC, contributed to conception and design and critical revision and final approval of the article. Michael D. Broglio, MS, contributed to conception and design; analysis and interpretation of the data; and drafting, critical revision, and final approval of the article. Timothy C. Sell, MS, PT, contributed to acquisition of the data and drafting and final approval of the article.

Address correspondence to Steven P. Broglio, MS, ATC, University of Georgia, 300 River Road, 110 Ramsey Center, Athens, GA 30602. Address e-mail to sbroglio@coe.uga.edu.

Objective: The potential for risks associated with chronic soccer heading has led some soccer leagues to mandate the use of soccer headgear. Although manufacturers have designed and promoted these headbands to decrease the forces associated with heading a soccer ball, their efficacy has not been tested. Therefore, we investigated the efficacy of 3 brands of soccer headgear: Headers, Headblast, and Protector, as compared with a non-headband condition.

Design and Setting: A force platform was mounted vertically with each headband attached with a length of hook-and-loop tape. A JUGS Soccer Machine projected balls at the platform and headband at 56.45 kph (35 mph).

Measurements: We measured vertical ground reaction force for 50 trials of each condition and calculated peak force, time to peak force, and impulse.

Results: We found a significant reduction in peak force of impact with all 3 headbands. The Protector headband also showed the greatest decrease in time to peak force and impulse, whereas the Headers headband showed a significant increase in impulse.

Conclusions: All 3 headbands were effective at reducing the peak impact force. The Protector headband appeared the most effective at reducing time to peak force and impulse within the design of this study. The clinical effectiveness of these products remains to be seen.

Key Words: soccer heading, impact force, head injury

Soccer is considered the world's most popular team sport with nearly 200 million participants.[1] In the United States, the success of the USA National Teams in international competition has led the way for an increase in youth soccer popularity. Soccer participation has increased 20% among youth (12–17 years of age) from 1997 to 1999.[2]

During soccer play, one aspect of ball control and advancement is the intentional and direct use of the athlete's head. Over a career of 300 games, a soccer athlete sustains an estimated 2000 blows to the head from heading a soccer ball in game situations.[3] The total number of headers taken during practice is likely to be much higher, although a specific number has not been reported. In recent years, some authors have criticized this technique for subjecting the soccer athlete to impact forces similar to those a boxer receives when struck in the head. Although the intents of repeated blows to the head in soccer and boxing differ, some researchers suggest the collective effect of soccer heading may be similar to years of boxing.[4–6] Some investigators propose chronic soccer heading may lead to neurocognitive deterioration.[7–9] Other experts have suggested the soccer athlete is at no risk for neurocognitive damage from heading.[10–12] To date, no researchers have provided definitive evidence for one side or the other.

During a boxer's career of 60 to 100 amateur and professional bouts, he or she sustains numerous blows to the head.[13] Most individual punches are subconcussive and likely have a negligible effect. The cumulative result of years of exposure, however, may be deleterious outcomes similar to those associated with concussion.[14–16] Those individuals sustaining a single concussive blow to the head can suffer from decreased information-processing skills.[17] The outcome for repeated exposure to minor head injuries appears less clear. A second injury may not only diminish information processing but also increase recovery time.[18] Conflicting injury-outcome evidence exists in children younger than 10 years who sustained multiple mild head injuries. The authors found intelligence and academic deficits to be unrelated to the head injuries. Other factors, such as socioeconomic status, may influence injury outcome.[19]

Boxing officials have required headgear at some levels of competition in an attempt to decrease the likelihood of injury. The design strategy for this equipment is to dissipate the force of impact from a punch to the head. A decrease in impact force from a blow may reduce the acceleration of the brain within the cranium,[20] lessening the chance of injury by impact and shear trauma. Until recently, an analogous piece of equipment to protect the head had not been available to the soccer athlete. Soccer headgear is now being offered to athletes as a means to protect them from the impact of soccer heading.

Manufacturers claim the headbands can decrease the force of a soccer ball, but only recently has one group assessed soccer headband efficacy.[21] Before this study, however, a middle school soccer league in Milwaukee and a youth soccer league in California mandated the use of soccer headgear. Currently, no regulations exist within the National Collegiate Athletic Association or Federation Internationale de Football Association (FIFA) rule books on the use of soccer headgear. Researchers have not conducted investigations of the noncom-

Figure 1. The JUGS Soccer Machine. Photograph courtesy of the Jugs Co.

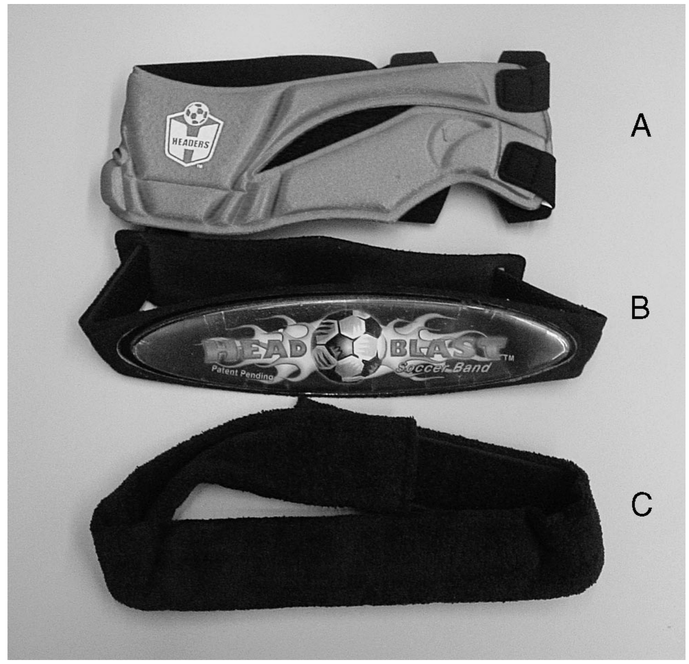

Figure 2. A, Headers. B, Headblast. C, Protector.

pulsory soccer headgear use, although Canadian rugby players have indicated they are not inclined to wear helmets even if proven effective at reducing injury rates.[22] Our purpose was to compare the effectiveness of 3 types of soccer headgear—Headers (the Headers name has since changed to Full90, Full90 Sports, Inc, San Diego, CA); Headblast (Benian's Enterprises LLC, St. Louis, MO); and Protector (soccerheadband.com, Brandon, SD) soccer headbands—in reducing impact from a linear blow by a soccer ball as measured by peak force of impact, time to peak force, and impulse.

METHODS

A force platform (type 9286A, Kistler Instruments, Inc, Winterthur, Switzerland) was mounted to a vertical I-beam with two 11.43-cm (4.5-in) Pony clamps (model 26545, Adjustable Clamp Co, Chicago, IL). The I-beam was part of the structure of an indoor athletic practice facility. A thin strip of cloth was placed between the clamp and the force platform to provide a firm grip during the testing session. A 1.27-cm (0.5-in)-thick piece of cardboard was placed at the bottom of the platform during mounting to ensure it would not rub against the ground during the testing session. The cardboard was removed once the clamps had secured the force platform against the beam.

We interfaced the Kistler force platform with a desktop computer via 16-bit analog to a digital converter board (model CIO-DAS1602/16, Measurement Computing, Middleboro, MA). All data were recorded using the Bioware software (version 3.20, Kistler Instruments). Each trial was 5 seconds in duration, with data collected at 5208 Hz, the maximum allowed by the Bioware software.

We positioned a JUGS Soccer Machine (JUGS Intl, Tualatin, OR; Figure 1) in front of the platform with the ball exit 1.52 m (60 in) from the front surface of the force platform. This position was checked regularly throughout the testing sessions to ensure no movement had taken place during testing. We turned on the Soccer Machine and adjusted the speed dials to 56.45 kph (35 mph), the desired exit velocity of the ball. This speed was selected as an estimate of youth soccer ball speed based on reported estimates from adults.[23] The machine was allowed to warm up for 5 minutes before testing.

Five size-5 FIFA-inspected soccer balls (Gamarada Club Pro, Adidas America, Portland, OR) were inflated to the manufacturer's recommended air pressure of 0.7 bars. Data collection was completed over a 2-day period, and the balls were checked for air loss on the second day, with adjustments made as necessary.

Fifty trials were completed for each of the 4 conditions: no headgear (control), Headers, Headblast, and Protector headbands (Figure 2). Fifty trials were selected to provide the best estimate of the mean effect for each condition.

The Headers headband is constructed of closed-cell foam laminated to the external material. The Headblast headband is a flexible piece of plastic attached to a thin neoprene headband. The Protector headband is of similar thickness to the Headers headband but contains a hard plastic insert backed with foam and fitted into a terry-cloth headband.

The Headblast and Protector were secured around the force platform with an extra length of hook-and-loop tape attached to the closing mechanism on the band. We cut the elastic of the Headers headband in the back and secured it to the platform with an extra length of hook-and-loop tape. Before each trial, we took the voltage offset to calibrate the force of the clamping mechanism. We carried out all 50 trials for each condition before proceeding to the next, and each soccer ball was randomly selected for use to ensure even wear. We fed soccer balls into the Soccer Machine and launched according to the manufacturer's instructions. Contact with the center of the headband by the soccer ball on each trial was confirmed visually.

Vertical reaction force (F_z) for each trial recorded by the Bioware software allowed for the calculation of peak impact force, time to peak force, and impulse of each impact through a custom data-analysis software in LabVIEW (version 5.1, National Instruments Corp, Austin, TX).

Data Analysis

Peak force was defined as the maximal reaction force that resulted from the impacting soccer ball as measured by the force-platform software. This value was calculated as the force difference between the time the force curve exceeded 2 standard deviations of the rest period before impact and the peak force of impact. Two standard deviations represent a 95% increase in the mean resting force, a value sufficient to prevent

Peak Force, Time to Peak Force, and Impulse (Mean ± SD)

Condition	Peak Force (N)	Time to Peak Force (ms)	Impulse (N•s)
No headband (n = 50)	3178.300 ± 265.133	8.356 ± 1.255	9.972 ± 0.315
Headers headband (n = 50)	2823.326 ± 186.621*	8.026 ± 2.042	10.468 ± 0.706†
Headblast headband (n = 50)	2749.128 ± 160.270*	8.233 ± 1.523	9.975 ± 0.401
Protector headband (n = 50)	2773.687 ± 179.298*	6.463 ± 1.160†	8.860 ± 0.416†

*Significant ($P < .05$) compared with no-headband condition.
†Significant ($P < .05$) compared with all other conditions.

erroneous calculations from the resting force platform's natural vibration. Time to peak force was the time interval between the rise in force (2 standard deviations above baseline) and the time peak force occurred. Calculating impulse estimates the total amount of momentum transferred by the impacting soccer ball. We calculated impulse from the area under the force curve from the beginning to the end of the impacting force. Using SPSS (version 9.0, SPSS Inc, Chicago, IL), we carried out separate 1-way analyses of variance to test for significant differences in peak force of impact, time to peak force, and impulse of impact. Tukey post hoc analyses were conducted if significant main effects were found between variables on any factor. Alpha was set a priori at .05.

RESULTS

Significant group main effects were noted for peak force ($F_{3,196} = 49.35$, $P < .001$), time to peak force ($F_{3,196} = 46.52$, $P < .001$), and impulse ($F_{3,196} = 99.23$, $P < .001$; Table). Tukey post hoc analysis for peak force revealed a significant decrease ($P < .001$) between all headband conditions and the no-headband condition. No difference in peak force was found among the different brands of headbands ($P > .05$).

Time-to-peak-force post hoc analysis also showed a significant decrease ($P < .001$) by the Protector condition when compared with the no-headband, Headers, and Headblast conditions. No significant difference ($P > .05$) was found between the Headers or Headblast conditions when compared with each other or the no-headband condition.

A final post hoc analysis of impulse revealed the Protector headband significantly decreased impulse when compared with the no-headband, Headers, and Headblast conditions ($P < .001$). The Headers condition, however, showed a significantly higher impulse when compared with the no-headband, Headers, and Headblast conditions ($P < .001$). No difference existed between the no-headband and Headblast conditions ($P = 1.000$).

DISCUSSION

Manufacturers of soccer headbands have designed them to decrease the forces associated with heading, assuming this will reduce the risk of head trauma. To date, however, only one study has been conducted to evaluate their efficacy.[21] The most substantial finding of this study is the decrease in peak force of impact from a soccer ball traveling at 56.45 kph (35 mph) with the application of the soccer headbands. Although no difference existed among the different brands of headbands, the decrease in force suggests that a soccer athlete wearing any of the headbands tested would be subjected to lower forces. The force decrease is approximately 12.5% lower (nearly 400 N) compared with the unprotected force platform. Naunheim et al[21] reported a similar percentage decrease in peak acceleration from a high-pressure soccer ball traveling at 34 mph with the use of soccer headgear.

The peak forces from impact recorded in our study are higher than the previously reported values of 851 to 912 N measured in unprotected heading scenarios with soccer balls traveling at similar speeds.[24,25] The mean peak forces recorded for the no-headband condition, however, approached 1000 N less than the peak contact force produced by a professional boxer.[26] This value is approximately half the estimated maximal peak force transmitted to an opponent for the same boxer.[26] This difference in impact forces may suggest that heading a soccer ball at 56.45 kph does not pose the same risk as receiving a boxing punch.

We speculate that the differences in peak force recorded in this study compared with previous work are associated with greater ball acceleration generated by the Soccer Machine. Levendusky et al[24] reported impact speeds of 38 to 40 mph (61.16–64.37 kph) when dropping a ball from 18.29 m (60 ft), but they recorded forces of impact nearly one third less than the measures of the current study. The Soccer Machine generated similar impact speeds within 1.5 m (5 ft) of the point of impact. Taking the Newton law of force = mass × acceleration into account, acceleration is the change in velocity divided by the change in time. In both studies, velocities were similar, but change in time for the Levendusky et al study[24] was much greater than ours. The time it took for the ball to travel 18.29 m was greater than the time it took for a ball to travel 1.5 m. Dividing a similar change in speed by a larger change in time results in a smaller ball acceleration. We assume the ball masses to be comparable, and multiplying by the smaller acceleration results in a smaller impact force.

In game and practice situations, it is feasible but unlikely that an athlete will take a header from a distance of 1.5 m. However, to measure soccer-headband efficacy directly, we took certain measures to control for extraneous variables. Athlete demographics should have been further considered when selecting ball size. Accounting for the youth soccer population for whom manufacturers design the headbands, a smaller size-4 ball may have been a more appropriate selection than the size-5 ball. The larger size-5 soccer ball can weigh 27 to 141 g more than a size-4 ball.[23] The force = mass × acceleration equation suggests that the ball with a larger mass has a larger force output given a consistent acceleration.

The decrease in time to peak impact force seen with the Protector headband of 6.46 milliseconds compared with 8.36 milliseconds for the no-headband condition may be associated with the decreased peak impact force. The lower peak impact force for the Protector as compared with the no-headband condition may result from the smaller amount of time it takes to reach the peak force if both forces are applied at the same rate (Figure 3). Similar peak forces seen between the Protector condition and the other headband conditions imply that the

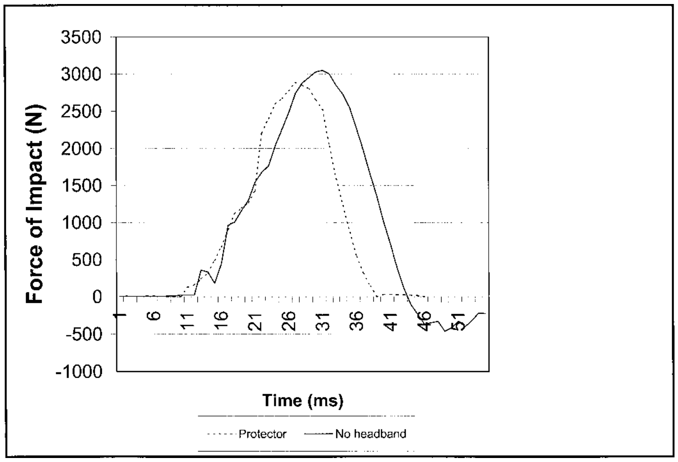

Figure 3. Mean impact of Protector versus no-headband condition.

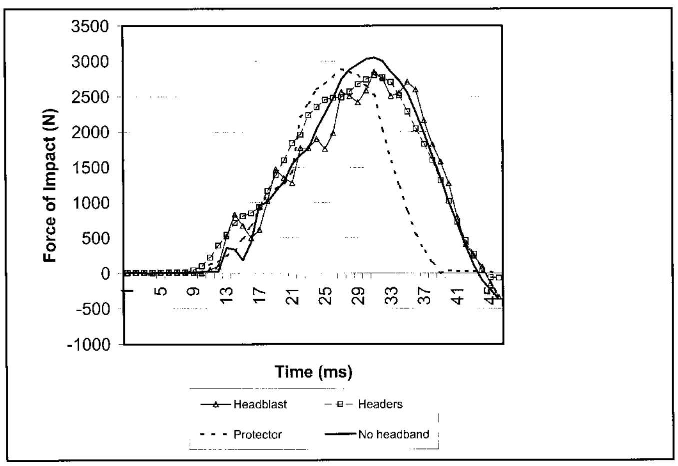

Figure 4. Mean impacts for all conditions.

Protector may have a reduced potential to protect an athlete from a soccer-ball impact. A similar peak impact force applied at the same rate, over a shorter time, gives body tissues less time to dissipate the applied load, increasing the chance for tissue damage.

The Headblast and Headers headbands showed no difference in time to peak force when compared with the no-headband condition, indicating that the rates of load for these 3 conditions are similar. However, because the headbands had a lower peak impact force than the no-headband condition, they had a decreased total effect of impact over the same time when compared with the no-headband condition. The values of time to peak impact for all conditions are similar to those reported previously for soccer-ball impacts[24,25] yet lower than the time to peak force of 14 milliseconds for the professional boxer.[26] This suggests a greater time of force distribution from a boxer's punch than an impacting soccer ball.

Differences in impulse among the various conditions recorded in this study represent the differences in momentum transmitted through the headband. These were measured while the ball was in contact with the force platform or headband. Impulse is the product of the average value of force over the time during which it acts and is measured in newton-seconds. This impulse is represented by the total area under the impact curve (Figure 4). The Headers headband showed a greater impulse compared with the other conditions, indicating the greatest transfer of energy through the headband to the force platform. The Headers headband also showed no difference in peak force when compared with the other headbands, suggesting that the total contact time of the soccer ball with the Headers headband is greater than the other headbands, allowing for a greater force transfer.

Conversely, the Protector headband showed the lowest values for the impulse variable. This suggests that the total force transmitted through the headband while the ball was in contact was less than all other conditions. However, no differences were observed between the peak forces of the different brands of headband, suggesting that the same maximal value of force was delivered through each headband. Because the Protector demonstrated the lowest impulse value, with no difference in peak force, the contact period between the ball and headband must be lower than the other conditions.

The use of headgear for soccer athletes is a controversial topic. Although some advocate the use of protective headgear for goalkeepers,[27] others have stated that protection for all athletes on the field should be a lightweight, soft-shell material. This equipment should fit snugly across the scalp and ''absorb and dissipate energy'' from soccer-ball impact.[28] The headbands tested in this study appear to fit the criteria suggested by Delaney and Drummond[28] of absorbing the force of impact through a decrease in peak force of impact from the soccer ball. The Protector headband showed the greatest dissipation of force through decreased time to peak force and impulse. In spite of these findings, several other factors, such as ball size and proper heading technique, warrant attention when considering the safety of the soccer athlete. The younger soccer athlete should use the smallest ball size, size 3, up to the age of 9 years, at which point a size-4 ball can be used. Once the athlete has turned 14 years old, use of the largest size, a size-5 ball, can begin.[29] The smaller ball size not only protects the athlete from impact with a heavier object, but it also affords greater control of the ball for the athlete who is still developing physically.

In all age groups, however, proper heading technique is the athlete's greatest defense against injury from heading a ball. Many coaching books do not address soccer heading until the age of 12 years, and some physicians recommend waiting until 14.[23] The younger soccer athlete who performs head balls may be at greater risk for injury because of smaller size, less muscular development, and a less skillful heading technique. Once soccer athletes begin heading, coaches should instruct them to strike the ball just below the hairline on the frontal bone, the thickest part of the cranium, while simultaneously isometrically contracting the neck musculature.[30] To counteract the force of the impacting ball, the athlete should apply a counterforce generated by moving the trunk into flexion.[23] By performing the maneuver as described, the body of the athlete becomes a single, rigid unit that lowers the risk of injury by decreasing the linear and rotational accelerations on the head as forces generated by the ball are dispersed across the athlete's body.[31]

If a forcefully kicked soccer ball collides with the head of an unprepared athlete, he or she may be at risk for concussion. In this scenario, the neck musculature does not maintain the head in a rigid position at ball impact, forcing the cranium into the brain and resulting in a coup injury. If the brain then rebounds into the opposite side of the inner cranium, a contrecoup injury can result.[32]

Although our findings indicate that headgear designed for the soccer athlete may be effective at reducing the peak force and impulse from an impact, further testing is warranted before soccer officials require them for regular play. The flat surface of the force platform is not representative of the human head, and the distance between the Soccer Machine and the force platform was closer than what normally occurs in practice and game situations. Finally, we tested only a limited number of variables for these soccer headbands under one speed. Collection of both linear and rotational acceleration variables may provide beneficial information on the headbands' ability to protect the brain from trauma. As such, conducting in vivo studies during both soccer games and practices in which accelerations of the head are recorded and analyzed is warranted.

Soccer officials should also consider several other questions that may alter game play should soccer headgear be mandated. The potential exists for the headgear to influence game outcomes by altering heading ball control or even player comfort. Also, soccer athletes may gain a false sense of security while wearing the headband and become overly aggressive when heading, thereby increasing their risk of injury.

CONCLUSIONS

Soccer is played at all age and skill levels around the world. The ball speed at which data on headband efficacy we collected seems to support the use of headbands in decreasing the force of an impacting soccer ball. Under the conditions of this study, the Protector headband appeared to perform the best across all variables. This headband, however, may be the most effective at decreasing the measured variables. Before a recommendation or mandate of soccer headgear use by all players on the field is made, further investigations of these products should be conducted to directly address their clinical utility.

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REFERENCES

1. Dvorak J, Junge A. Football injuries and physical symptoms: a review of the literature. *Am J Sports Med.* 2000;28(suppl 5):S3–S9.
2. Sporting Goods Manufacturer's Association. Available at: http://www.sportlink.com/press/ 1999/press985886366–4004.html. Accessed February 15, 2002.
3. Tysvaer A, Storli O. Association football injuries to the brain: a preliminary report. *Br J Sports Med.* 1981;15:163–166.
4. 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;24:205–210.
5. Sortland O, Tysvaer AT. Brain damage in former association football players: an evaluation by cerebral computed tomography. *Neuroradiology.* 1989;31:44–48.
6. Asken MJ, Schwartz RC. Heading the ball in soccer: what's the risk of brain injury? *Physician Sportsmed.* 1998;26(11):37–44.
7. Matser EJ, Kessels AG, Jordan BD, Lezak MD, Troost J. Chronic traumatic brain injuries in professional soccer players. *Neurology.* 1998;51: 791–796.
8. Matser JT, Kessels AG, Lezak MD, Jordan BD, Troopst J. Neuropsychological impairment in amateur soccer players. *JAMA.* 1999;282:971–973.
9. Tysvaer AT, Lochen EA. Soccer injuries to the brain: a neuropsychologic study of former soccer players. *Am J Sports Med.* 1991;19:56–60.
10. Carmack B, DeLaney H, Hambrick R, Hart J, Robinson K, Voight M. The effects of heading a soccer ball on postural stability in male and female college soccer players. Paper presented at: National Athletic Trainers' Association 51st Annual Meeting & Clinical Symposia, June 28–June 2, 2000; Nashville, TN.
11. Broglio SP, Guskiewicz KM. Soccer heading: are there risks involved? *Athl Ther Today.* 2001;6(1):28–32.
12. Guskiewicz KM, Marshall SW, Broglio SP, Cantu RC, Kirkendall DT. No evidence of impaired neurocognitive performance in collegiate soccer players. *Am J Sports Med.* 2002;30:157–162.
13. Carroll EJ. Punch-drunk. *Am J Med Sci.* 1936;191:706–712.
14. Ross RJ, Cole M, Thompson JS, Kim KH. Boxers: computed tomography, EEG, and neurological evaluation. *JAMA.* 1983;249:211–213.
15. Ross RJ, Casson IR, Siegel O, Cole M. Boxing injuries: neurologic, radiologic, and neuropsychologic evaluation. *Clin Sports Med.* 1987;6:41–51.
16. Corsellis JA, Bruton CJ, Freeman-Browne D. The aftermath of boxing. *Psychol Med.* 1973;3:270–303.
17. Gronwall D, Wrightson P. Delayed recovery of intellectual function after minor head injury. *Lancet.* 1974;2:605–609.
18. Gronwall D, Wrightson P. Cumulative effect of concussion. *Lancet.* 1975; 2:995–997.
19. Bijur PE, Haslum M, Golding J. Cognitive outcomes of multiple mild head injuries in children. *J Dev Behav Pediatr.* 1996;17:143–148.
20. Lewis LM, Naunheim R, Standeven J, Lauryssen C, Richter C, Jeffords B. Do football helmets reduce acceleration of impact in blunt head injuries? *Acad Emerg Med.* 2001;8:604–609.
21. Naunheim RS, Ryden A, Standeven J, et al. Does soccer headgear attenuate the impact when heading a soccer ball? *Acad Emerg Med.* 2003;10: 85–90.
22. Pettersen JA. Does rugby headgear prevent concussion? Attitudes of Canadian players and coaches. *Br J Sports Med.* 2002;36:19–22.
23. Kirkendall DT, Jordan SE, Garrett WE. Heading and head injuries in soccer. *Sports Med.* 2001;31:369–386.
24. Levendusky T, Armstrong C, Eck J, Jeziorowski J, Kugler J. Impact characteristics of two types of soccer balls. In: Reilly T, Lees A, Davids K, Murphy W, eds. *Science and Football.* London, England: Routledge; 1988:385–393.
25. Armstrong C, Levendusky T, Eck J, Spyropoulos P, Lugler L. Influence of inflation pressure and ball wetness on the impact characteristics of two types of soccer balls. In: Reilly T, Davids K, Murphy W, eds. *Science and Football.* London, England: Routledge; 1994:394–398.
26. Atha J, Yeadon MR, Sandover J, Parsons KC. The damaging punch. *Br Med J.* 1985;291:1756–1757.
27. Dailey SW, Barsan WG. Head injuries in soccer: a case for protective headgear? *Physician Sportsmed.* 1992;20(8):79–85.
28. Delaney JS, Drummond R. Has the time come for protective headgear in soccer? *Clin J Sport Med.* 1999;9:121–123.
29. Kirkendall DT, Garrett WE Jr. Heading in soccer: integral skill or grounds for cognitive dysfunction? *J Athl Train.* 2001;36:328–333.
30. Reid SE, Epstein HM, Louis MW, Reid SE Jr. Physiologic response to impact. *J Trauma.* 1975;15:150–152.
31. Lohnes JH, Garrett WE, Monto RR. Soccer. In: Fu FH, Stone DA, eds. *Sports Injuries.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2001:703–724.
32. Gross L. Boxing. In: Fu FH, Stone DA, eds. *Sports Injuries.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2001:320–351.