

# Pediatric Mild Traumatic Brain Injury

## *A Case Review*

Jason P. Mihalik, MS, CAT(C), ATC; Jared A. Jeffries, BA; Mario F. Ciocca, MD; and Kevin M. Guskiewicz, PhD, ATC, FACSM, FNATA

### ■ ABSTRACT

We present a case of pediatric mild traumatic brain injury sustained while participating in ice hockey. This injury occurred while the athlete was participating in a larger prospective clinical investigation of youth head injuries, especially as they pertain to injury biomechanics, neurocognition, and postural stability. This is a unique case in that objective data of this nature are rarely measured in the youth population. The clinical management of this case is presented in conjunction with these data.

Few areas of sports medicine have generated as much public interest in recent years as sports-related mild traumatic brain injury (TBI). Although media exposure has served to heighten the general awareness of this condition, more exploration is needed in the areas of postconcussive recovery, mechanisms of injury, return-to-play decisions, and rehabilitation. More than 1.4 million people sustain a TBI annually in the United States,<sup>1</sup> with some estimates suggesting as many as 1.6 to 3.8 million people.<sup>2</sup> Although 475,000 cases of TBI occur annually in children ages 0 to 14 years,<sup>1</sup> relatively little research has been performed on this susceptible population. The purpose of this case

report is to present a unique scenario involving pediatric mild TBI. The athlete was a participant in an ongoing research study.<sup>3</sup> As a result, we have preseason baseline and postinjury computerized neuropsychological data, postural stability data (Balance Error Scoring System [BESS]), and real-time biomechanical measurements of the injurious impact.

### CASE REVIEW

A 13-year-old male ice hockey player (height = 162.56 cm; mass = 50.0 kg) was checked from behind head first into the end boards. The athlete remained motionless on the ice in a supine position. An emergency medical technician and research assistant (J.A.J.) maintained cervical spine stabilization while completing the primary survey (UABC):

- The athlete was conscious and responsive (U).
- The athlete's mouthguard was removed (A).
- Breathing (B) and signs of circulation (C) were normal.
- A certified athletic trainer then arrived on scene and performed the secondary survey.

The athlete complained of a severe general headache and cervical neck pain that intensified on gentle palpation. Generalized neck pain was felt between the levels of C4 and T2 and extended into the right shoulder. Assessment of upper and lower extremity dermatomes and myotomes revealed no significant abnormalities. Primary vitals were reassessed every other minute. There were no changes in UABC status until emergency medical services personnel arrived approximately 10 minutes later. The injured athlete was secured onto a spine board and transported to a local general hospital.

Computed tomography scans of the head returned negative for all visible insults. The computed tomog-

---

Mr Mihalik, Mr Jeffries, and Dr Guskiewicz are from the Sports Medicine Research Laboratory, Department of Exercise and Sport Science, and Dr Ciocca is from the Division of Sports Medicine, Campus Health Services, The University of North Carolina, Chapel Hill, NC. Drs Mihalik and Guskiewicz are also from the Curriculum in Human Movement Science, Department of Allied Health Sciences, School of Medicine, The University of North Carolina, Chapel Hill, NC.

Originally submitted August 22, 2008.

Accepted for publication October 31, 2008.

Address correspondence to Jason P. Mihalik, MS, CAT(C), ATC, Sports Medicine Research Laboratory, Department of Exercise and Sport Science, The University of North Carolina, 209 Fetzer Gymnasium, South Road, Chapel Hill, NC 27599; e-mail: jmihalik@email.unc.edu.

raphy scan of the right shoulder revealed acromioclavicular joint widening. The athlete was diagnosed with a concussion and acromioclavicular joint sprain. He was discharged from the emergency department with instructions to follow-up with his pediatrician. The next morning, the athlete was reevaluated by the certified athletic trainer. At this time, it was discovered that in addition to experiencing 5-hour retrograde amnesia, the athlete also experienced complete 4-hour anterograde amnesia. The athlete was referred to a sports medicine physician familiar with the recognition and management of concussions and musculoskeletal injuries.

Acutely, the athlete's injury was managed by stabilizing the cervical spine, immobilizing him onto a spine board, and transporting him to a medical facility. After he was released from the hospital, the athlete was reevaluated by a physician 3, 11, and 24 days postinjury. On these days, a certified athletic trainer administered a computerized neurocognitive test battery (Immediate Postconcussion Assessment and Cognitive Test [ImPACT]; ImPACT Applications, Inc, Pittsburgh, Pa), assessed the patient's postural stability (Sensory Organization Test), and evaluated the presence and severity of postconcussion symptoms. The athlete was advised to abstain from all activity, with the exception of range of motion and light strengthening exercises for his injured shoulder. Eleven days following injury, horizontal humeral adduction still caused discomfort in the acromioclavicular joint. At this time, neuropsychological testing had returned to preseason baseline levels. Noncontact activity did not cause a regression in symptom status in this athlete, and the shoulder continued to progress through rehabilitation as expected and with no further complications. The athlete underwent a graduated return to play protocol, eventually returned to full participation (24 days postinjury), and did not experience another shoulder or head injury event for the remainder of the season.

## DISCUSSION

This case represents a unique exploration of mild TBI in a young athlete as it pertains to injury biomechanics, postinjury evaluation, and injury management. Because this athlete was participating in an ongoing prospective clinical study of mild TBI in youth ice hockey players, we were fortunate to have preseason baseline data on a number of clinical measures of concussion commonly used by certified athletic trainers. Although it is not the purpose of this case report to describe the methods in

full detail, its discussion is rendered difficult without a description of these measures.

## Methodological Procedures

We used commercially available ice hockey helmets modified to accept Head Impact Telemetry System technology to measure head acceleration in all games and practices for every skater on a youth ice hockey team. When a head impact occurs, the data are collected and then transmitted in real time to a sideline laptop system. A more detailed description of this instrumentation has been previously published.<sup>3</sup> In addition to the biomechanical data related to head impact severity, we also record a number of clinical measures of mild TBI including the ImPACT, Standardized Assessment of Concussion (SAC), BESS, and Postconcussion Symptom Scale (PCSS). We use these tools in particular because they are familiar to many certified athletic trainers and are easy to administer while traveling with the players or at sites located off campus. In this case, the athlete visited us for medical follow-up evaluations and, as such, we were also able to evaluate his postural stability using the Sensory Organization Test (SOT).

The ImPACT is a computerized neurocognitive test battery that consists of 7 individual test modules, which measure aspects of cognitive functioning including attention, memory, reaction time, and information processing speed. A thorough description of the ImPACT test battery and rationale for the development of the individual tests has been described in detail previously.<sup>4</sup> The SAC<sup>5</sup> includes measures of orientation, immediate memory, concentration, and delayed recall, as well as a total score (maximum = 30). A standard neurologic screening is embedded in the SAC and includes an assessment of strength, sensation, and coordination. The occurrence and duration of loss of consciousness, retrograde amnesia, and posttraumatic amnesia is also recorded on the SAC. The BESS<sup>6</sup> is a sideline postural stability evaluation tool consisting of 6 tasks composed of 3 different stances (double-leg, single-leg non-dominant limb, and tandem stances) performed on 2 surface conditions (firm and foam). Errors in performance are recorded and tabulated for a total error score. The PCSS is included in the ImPACT and is designed to evaluate both the presence and severity of 22 symptoms commonly associated with concussion. The PCSS uses a Likert scale for each symptom, ranging from 0 (*asymptomatic*) to 6 (*severely symptomatic*). Finally, the SOT is able to assess balance performance by disrupt-

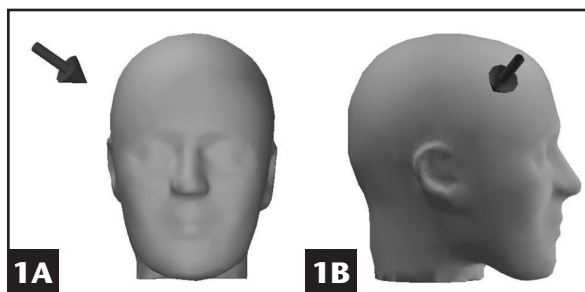


Figure 1. Graphical illustration of impact location and direction from anterior (A) and lateral (B) views. The linear acceleration of the collision was measured at 100.19 g.

ing input from the visual, vestibular, and somatosensory systems. Participants complete three 20-second trials of 6 different sensory conditions in random order. The SOT has been previously described in detail.<sup>7</sup>

### Biomechanical Characteristics of Injury

The linear head acceleration related to this injury was measured at 100.19 g and was directed through the top-right portion of the player's head (Figure 1). The linear acceleration of this injurious impact was greater than the proposed theoretical injury thresholds based on laboratory reconstruction of video footage of injured professional football players.<sup>8,9</sup> It also falls within the top 2% of impact magnitudes we have collected during 3 years in Division I collegiate football players.<sup>10</sup> This is alarming given the relative small stature of our ice hockey player. The injurious impact was among the top 1% in severity among his teammates over the course of the hockey season and was also the most severe head impact the player himself sustained during the season.

Further complicating the issue of head trauma in ice hockey is the presence of boards. In this case, our player was illegally hit from behind into an unmovable board with no give in its design. As a result, the force associated with this impact was almost entirely absorbed by our player and his equipment. We believe the force of the in-board collision and the cervical spine left side-bending mechanism contributed to the acromioclavicular joint sprain in addition to the mild TBI. The use of protective shoulder pads likely limited the severity of the concomitant shoulder injury. All levels of ice hockey (amateur and professional) have banned hitting from behind. This case highlights that, although rule changes have been implemented to reduce the risk of severe injury, illegal hits still do occur. Although our athlete did not sustain a cata-

strophic injury, the mild TBI and shoulder injury kept him out of play for almost 1 month.

### Neurocognitive Function Following Injury

Follow-up testing using the ImpACT and SAC were performed on days 2, 3, 4, and 11. A certified athletic trainer (J.P.M.) well experienced in the administration and interpretation of the ImpACT and SAC performed all of the testing. Verbal memory appeared unaffected, and improvements in performance in this regard were observed. Explanations for these improvements are speculative at best. One possible explanation is that the areas of the brain responsible for contributing to verbal memory were not directly affected in this case. Given that no formal computerized testing was performed prior to day 2, it is possible that immediate deficits as a result of the injury may have resolved within 48 hours. In contrast, deficits in visual memory were still apparent 2 days following injury. Visual memory performance decreased further on day 3. The athlete admitted to participating in a light dry-land exercise with the team the night before. We theorize that the exertion while the athlete was still symptomatic catalyzed the decrease in performance in this regard. Although little research in this area exists, Majerske et al<sup>11</sup> demonstrated significant deficits in neurocognitive measures in young athletes who participate in higher levels of activity (ie, return to school and practice activities, return to play) while still injured, compared with those who do not. Visual memory improved by day 4 and remained constant at day 11. Reaction time, a measure sensitive to mild TBI,<sup>12,13</sup> followed a similar trend to visual memory—that is, decreased performance on day 2, deteriorating further into day 3, improving on day 4, and baseline normal by day 11 (Figure 2). In this case, the SAC did not appear sensitive to identifying gross mental status changes 2 days postinjury; this is in agreement with previous research suggesting the SAC is only sensitive to subtle changes due to concussion within 24 to 48 hours of the injury.<sup>14</sup>

### Postural Stability Assessment

Our ongoing research study includes the BESS as a clinical measure of postural stability. Although it was not originally a part of our ongoing project, the SOT was performed on postinjury days 3, 11, and 24. We used the scores obtained on day 24, when the athlete was fully rehabilitated and cleared for play, as a substitute for what we would have expected under preseason baseline test-

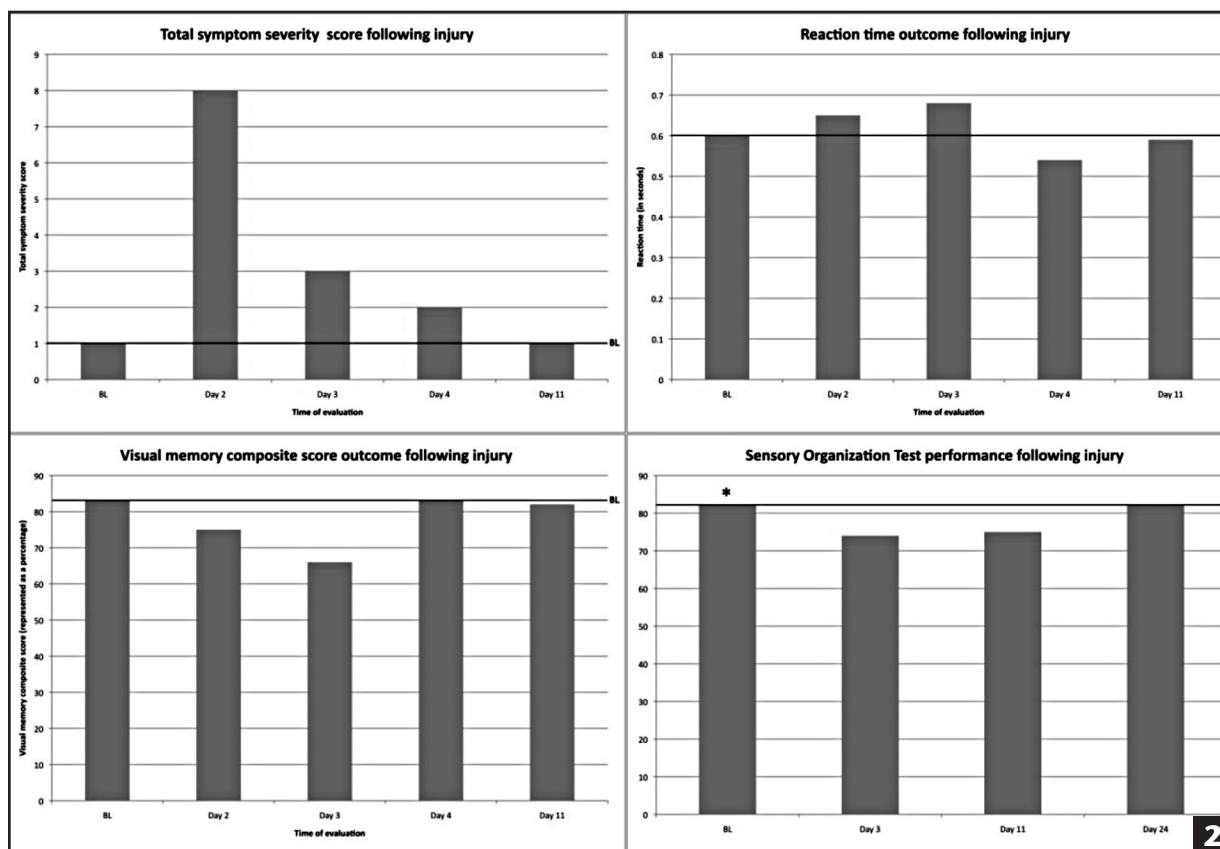


Figure 2. Total symptom severity scores, reaction time composite scores, visual memory composite scores, and Sensory Organization Test equilibrium scores. The asterisk (\*) represents an estimation of preinjury baseline based on day 24 scores. Solid lines indicate the baseline (BL) scores and how they relate to our athlete's recovery scores.

ing. The overall equilibrium score obtained from the SOT assessment on day 3 revealed diminished postural stability. Balance performance remained diminished as late as day 11. The athlete was also experiencing impairments in his ability to correctly use visual and vestibular information from his surroundings. These impairments were observed on day 3 and continued to drop as late as day 11. These findings are interesting, given ImPACT test scores suggest cognitive recovery occurred by day 11. In the absence of alternative objective measures (ie, postural stability), this athlete may have been prematurely returned to participation. The results obtained by assessment with the BESS support our findings of the SOT evaluation. The athlete appeared near baseline on day 2 and experienced the most severe postural deficits on day 11. These results and those of the SOT are a testament to why multiple testing measures should be applied when determining recovery status of any concussed individual, especially in youth athletes. In some of our earlier work with Division I football players, top-of-helmet impacts

resulted in some of the largest declines in postural stability.<sup>15</sup> We speculate impacts approaching the top of the helmet result in coup-contrecoup movement of the brain in a superior-inferior direction, thereby disrupting the cerebellum's homeostasis by impacting the cerebellar tentorium (superiorly) and the base of the skull (inferiorly). The brain center responsible for the integration of vestibular, visual, and somatosensory information may be impaired resulting in another plausible explanation for this phenomenon. It is important for certified athletic trainers to use objective clinical measures of concussion, in addition to their patient history, to better understand and interpret their findings. By doing so, certified athletic trainers will be better equipped to manage these difficult injuries that often manifest themselves in different ways.

#### Traumatic Brain Injury in Youth Ice Hockey

Limited epidemiological data exist describing mild TBI in youth ice hockey. Gerberich et al<sup>16</sup> reported an injury rate of 75 injuries per 100 high school ice hockey players,

with 22% of all injuries represented by head and neck injuries. Stuart et al<sup>17</sup> reported Bantam-aged ice hockey players (represented by the athlete in this case report) were almost 2.5 to 4 times more likely of sustaining an injury than their younger counterparts. Our athlete was injured as a direct result of an illegal check from behind; Brust et al<sup>18</sup> reported that 39% of all game-related collision injuries resulted from illegal checking and only 20% occurred from legal collisions. In addition, 86% of all game-related injuries resulted from checking and illegal game infractions. Others have reported the prevalence of body collision-related injuries in youth ice hockey to account for as many as 65%<sup>19</sup> and 75%<sup>20</sup> of all injuries observed in their samples.

## CONCLUSION

The player's helmet was fitted with accelerometers capable of measuring the magnitude of head acceleration, as well as location and direction of head impact, following each body collision sustained during games and practices. In addition, we had extensive preseason baseline measures on the ImPACT, SAC, and BESS, of which we performed postinjury testing to help the physician document and manage the athlete's recovery and safe return. Although we did not have preseason baseline measurements on the SOT, postinjury SOT data were collected and are discussed in this report.

This case report represents an interesting research and clinical paradigm as it pertains to the study of pediatric mild TBI. As more injuries are collected with novel biomechanical instrumentation in this population, we may begin to understand more fully the mechanisms of injury, forces related to the injury, and associated clinical manifestations, of pediatric mild TBI. As we have seen some young athletes recover from mild TBI in less than 11 days, and have seen others take much longer than 11 days, we caution against a blanket management approach of withholding young athletes out of play for 11 days based solely on the findings of this individual case report. We think this case exemplifies the clinical importance of managing each case of mild TBI independently, while relying on a strong clinical understanding of a multifaceted approach in addressing mild TBI in this young population. ■

## REFERENCES

- Langlois JA, Rutland-Brown W, Thomas KE. *Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations, and Deaths*. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2004.
- Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: A brief overview. *J Head Trauma Rehabil*. 2006;21:375-378.
- Mihalik JP, Guskiewicz KM, Jeffries JA, Greenwald RM, Marshall SW. Characteristics of head impacts sustained by youth ice hockey players. *Proc Inst Mech Eng [P]*. 2008;222:45-52.
- Maroon JC, Lovell MR, Norwig J, Podell K, Powell JW, Hartl R. Cerebral concussion in athletes: Evaluation and neuropsychological testing. *Neurosurgery*. 2000;47:659-669.
- McCrea M. Standardized mental status assessment of sports concussion. *Clin J Sport Med*. 2001;11:176-181.
- Riemann BL, Guskiewicz KM. Effects of mild head injury on postural stability as measured through clinical balance testing. *J Athl Train*. 2000;35:19-25.
- Guskiewicz KM, Ross SE, Marshall SW. Postural stability and neuropsychological deficits after concussion in collegiate athletes. *J Athl Train*. Sep 2001;36:263-273.
- Pellman EJ, Viano DC, Tucker AM, Casson IR, Waeckerle JF. Concussion in professional football: Reconstruction of game impacts and injuries. *Neurosurgery*. 2003;53:799-812.
- Zhang L, Yang KH, King AI. A proposed injury threshold for mild traumatic brain injury. *J Biomech Eng*. 2004;126:226-236.
- 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;61:1229-1235.
- Majerske CW, Mihalik JP, Ren D, et al. Concussion in sports: Postconcussive activity levels, symptoms, and neurocognitive performance. *J Athl Train*. 2008;43:265-274.
- Iverson GL, Lovell MR, Collins MW. Validity of ImPACT for measuring the effects of sports-related concussion. *Arch Clin Neuropsychol*. 2002;17:769.
- Iverson GL, Lovell MR, Collins MW. Validity of ImPACT for measuring processing speed following sports-related concussion. *J Clin Exp Neuropsychol*. 2005;27:683-689.
- 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;290:2556-2563.
- Guskiewicz KM, Mihalik JP, Shankar V, et al. Measurement of head impacts in collegiate football players: Relationship between head impact biomechanics and acute clinical outcome after concussion. *Neurosurgery*. 2007;61:1244-1253.
- Gerberich SG, Finke R, Madden M, Priest JD, Aamothe G, Murray K. An epidemiological study of high school ice hockey injuries. *Childs Nerv Syst*. 1987;3:59-64.
- Stuart MJ, Smith AM, Nieva JJ, Rock MG. Injuries in youth ice hockey: A pilot surveillance strategy. *Mayo Clin Proc*. 1995;70:350-356.
- Brust JD, Leonard BJ, Pheley A, Roberts WO. Children's ice hockey injuries. *Am J Dis Child*. 1992;146:741-747.
- Roberts WO, Brust JD, Leonard B. Youth ice hockey tournament injuries: Rates and patterns compared to season play. *Med Sci Sports Exerc*. 1999;31:46-51.
- Bernard D, Trudel P, Marcotte G, Boileau R. The incidence, types, and circumstances of injuries to ice hockey players at the Bantam level (14 to 15 years old). In: Castaldi CR, Bishop PJ, Hoerner EF, eds. *Safety in Ice Hockey: Second Volume, ASTM Special Technical Publication 1212*. Philadelphia, PA: American Society for Testing and Materials; 1993:44-55.

Copyright of Athletic Training & Sports Health Care: The Journal for the Practicing Clinician is the property of SLACK Incorporated and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.