DOES AGE PLAY A ROLE IN RECOVERY FROM SPORTS-RELATED CONCUSSION? A COMPARISON OF HIGH SCHOOL AND COLLEGIATE ATHLETES

MELVIN FIELD, MD, MICHAEL W. COLLINS, PHD, MARK R. LOVELL, PHD, AND JOSEPH MAROON, MD

Objective To evaluate symptoms and neurocognitive recovery patterns after sports-related concussion in high school and college athletes.

Study design College athletes (n = 371) and high school athletes (n = 183) underwent baseline neuropsychological evaluation between 1997 and 2000. Individuals who received a concussion during athletic competition (n = 54) underwent serial neuropsychologic evaluation after injury and were compared with a noninjured within-sample control group (n = 38). Main outcome measures included structured interview, four memory measures, and Concussion Symptom Scale ratings. Baseline to postinjury change scores and multiple analyses of variance were used to compare recovery curves within and between groups.

Results High school athletes with concussion had prolonged memory dysfunction compared with college athletes with concussion. High school athletes performed significantly worse than age-matched control subjects at 7 days after injury ($F = 2.90$; $P < .005$). College athletes, despite having more severe in-season concussions, displayed commensurate performance with matched control subjects by day 3 after concussion. Self-report of postconcussion symptoms by student athletes was not predictive of poor performance on neuropsychologic testing.

Conclusions Caution and systematic evaluation should be undertaken before returning athletes with concussion to competition. Sole reliance on the self-report of the athlete may be inadequate. Preliminary data may suggest a more protracted recovery from concussion in high school athletes. (*J Pediatr 2003;142:546-53*)

The diagnosis, recovery, and treatment of sports-related mild traumatic brain injury (MTBI; eg, concussion) has rightfully received recognition as a major public health concern.[1] An estimated 62,816 cases of MTBI occur annually at the high school level, with football accounting for approximately 63% of the cases.[2] At the college level, a multicenter study found that 34% of college football players had one concussion in their past, whereas 20% had multiple concussions.[3] The latter study also revealed associated neuropsychologic impairment (eg, speed of information processing, problem solving) in the multiple concussion group, with learning disability found to be an associated risk factor. Colleagues from the Netherlands have similarly revealed neuropsychologic impairment (eg, planning, memory) in a group of adult amateur soccer players.[4] In addition to these systematic research efforts, the National Hockey League mandates baseline neuropsychologic evaluation for all athletes, and the majority of National Football League organizations have implemented neuropsychologic testing to help with clinical decision-making after concussion.[5]

Though systematic research and clinical efforts have been fruitful and are underway with many college and professional teams, there has been a paucity of systematic or published research examining the acute recovery of adolescent and high school athletes after concussion.

Recently, the American Academy of Pediatrics outlined the clinical pathway for treating general minor traumatic brain injury.[6] These parameters primarily address ruling

AAN	American Academy of Neurology	LOC	Loss of consciousness
BVMT-R	Brief Visual Spatial Memory Test–Revised	MANOVA	Multiple analysis of variance analyses
EAA	Excitatory amino acids	MTBI	Mild traumatic brain injury
GPA	Grade point average	NMDA	*N*-methyl-D-aspartate
HVLT	Hopkins Verbal Learning Test	PTA	Post-traumatic amnesia
LD	Learning disabilities	TBI	Traumatic brain injury

From the Departments of Neurological Surgery and Orthopedic Surgery, University of Pittsburgh School of Medicine Center for Sports Medicine, Pittsburgh, Pennsylvania.

Submitted for publication May 10, 2002; revision received Oct 24, 2002; accepted Feb 14, 2003.

Reprint requests: Melvin Field, MD, Department of Neurological Surgery, University of Pittsburgh School of Medicine, PUH Suite B-400, 200 Lothrop St, Pittsburgh, PA 15213. E-mail: fieldm@msx.upmc.edu.

0022-3476/2003/$30.00 + 0
10.1067/mpd.2003.190

out serious intracranial pathology (eg, skull fracture, developing hematoma) and stress the importance of ongoing research in the area of MTBI in children.

The current prospective study was undertaken to compare preseason (ie, baseline) with postconcussion neuropsychologic and symptom recovery patterns in high school and college athletes.

METHODS

Subjects

Study subjects were college and high school athletes. The college sample consisted of 370 male football and 23 female soccer players from four Division 1A programs: Michigan State University, East Lansing; the University of Utah, Salt Lake City; the University of California, Berkeley; and Arizona State University, Tempe. The high school sample consisted of 161 varsity male football players and 22 varsity male soccer players from 5 high schools in Shiawassee County, Michigan.

Program Protocol and Outcome Measures

All athletes in the sample participated in the Concussion Safety Program. This voluntary ongoing clinical and research program implements the use of neuropsychologic tests to assist team medical staff in making objective decisions for return-to-play after the occurrence of sports-related concussion. All athletes in the program are individually administered neuropsychologic tests during the preseason, which then become the standard of comparison if the athlete is injured. Athletes are not financially compensated for participation in the program.

Preseason Baseline Evaluation

Appropriate review for research with human subjects was granted separately from the four college institutions. Each college participant provided written informed consent for voluntary participation. Parental consent for participation was also obtained for each athlete in the high school sample. Data collection for all athletes was completed by a research team of clinical neuropsychologists, team physicians, or athletic trainers who were formally trained in the administration of the measures. Each examiner was required to attend a 2-hour workshop and was supervised during test administration to facilitate the appropriate standardized administration of the test battery. All measures were administered and scored in a standardized manner to minimize differences between test administrators and institutions/high schools. Project investigators trained in neuropsychologic assessment completed all data scoring.

Baseline data collection for the college sample was initiated before the 1997/1998 athletic season and continued yearly up until the 2000/2001 season. High school baseline data collection was completed before the 1999/2000 and 2000/2001 seasons. All baseline data were collected during the off-season (eg, before preseason contact drills). At the baseline session, the following self-reported data were collected: age, playing position, college board examination scores (if applicable), grade point average, history of diagnosed learning disability, neurologic history (eg, epilepsy, brain tumor), psychiatric history (eg, depression, mania), and history of concussion. The standardized concussion history form was administered to gather information regarding specific incidences of concussion in the athlete's past. Concussion history information collected included: year of concussion, description of event, presence/length of confusion, loss of consciousness, anterograde amnesia (memory loss after the hit), retrograde amnesia (memory loss before the hit), and results of neuroimaging procedures (if any).

Concussions were defined and graded according the American Academy of Neurology (AAN) Practice Parameter.[7] Thus, players with a traumatically induced alteration in mental status, not necessarily resulting in loss of consciousness, were defined as having had a concussion. According to the AAN guidelines, a grade 1 concussion occurs when mental status changes resolve in <15 minutes after trauma. A grade 2 event occurs when mental status changes persist for >15 minutes after trauma. A grade 3 concussion occurs when there is an associated loss of consciousness (either brief or prolonged) after the trauma.

During the baseline session, all athletes were administered a Post-Concussion Symptom Scale that is now being used throughout amateur and professional sports.[8] This Likert scale consists of 20 symptoms commonly associated with concussion (eg, headache, dizziness, nausea, sleep disturbance) that are graded from 0 (asymptomatic) to 6 (severely symptomatic) in terms of severity.

After completing the Post-Concussion Symptom Scale, all athletes were administered a 25-minute battery of neuropsychologic tests. Tests included the Hopkins Verbal Learning Test (HVLT; verbal learning and memory); Digit Span Test (attention/concentration); Symbol Digit Modalities Test (speed of information processing); Trailmaking Test, Forms A and B (visual scanning and executive functioning), and Controlled Oral Word Association Test (word fluency). High school athletes were also administered the Brief Visual Spatial Memory Test-Revised (BVMT-R; visual memory). This test was added to the high school battery for the 1999/2000 season, since more time was available with this sample. A more thorough description of the specific cognitive tests and rationale for testing has been described in detail previously.[8]

Based on previous work with college athletes suggesting acute and demonstrable impairments of memory processes after concussion,[3] this study used memory tests as dependent measures. We also chose to focus on memory because of the primary importance of amnesia to virtually all current concussion management guidelines. Thus, our two dependent measures included the HVLT and BVMT-R. Each of these tests has a learning component to verbal or visual stimuli (3 consecutive immediate recall trials) and a delayed memory component (20 minutes after learning trial).

Postconcussion Evaluation

Although in-season concussions were graded on the basis of AAN criteria, the diagnosis of concussion was on the basis of the on-field presentation of one or more of the following symptoms after a blow to the head or body: (1) any observable alteration in mental status or consciousness; (2) a constellation of self-reported symptoms, such as posttraumatic headache, "fogginess," nausea/vomiting, dizziness, and so forth, and/or (3) the presence of loss of consciousness, disorientation, post-traumatic amnesia (PTA), or retrograde amnesia as identified by on-field examination. Initial diagnosis of concussion was made by sports medicine practitioners who were present on the sideline at the time of injury.

Sports medicine practitioners at the participating institutions carefully documented information pertaining to postconcussion markers of injury. At the aforementioned training seminars, athletic trainers and/or physicians were trained to identify the on-field markers of concussion, including disorientation, PTA, retrograde amnesia, and LOC. On-field disorientation was assessed by questioning the athlete's postinjury awareness and orientation to surroundings (eg, name, current stadium, city, opposing team, current month/day). Athletes with any level of on-field disorientation in this regard were classified in the positive disorientation group. On-field PTA was assessed through immediate and delayed (eg, 0, 5, 15 minutes) memory for three words (eg, girl, dog, green). PTA was subsequently documented at the postinjury follow-up evaluation by assessing the athlete's ability to recall all information subsequent to trauma. Any loss of memory in this latter regard indicated positive presence of PTA. On-field retrograde amnesia was assessed by having the athlete recall events occurring just before trauma (eg, memory for play or plays preceding trauma, events in previous quarter, and so forth). Retrograde amnesia was subsequently documented at the postinjury evaluation by assessing the athlete's ability to recall information just before trauma. Any loss of memory in this latter regard indicated positive presence of retrograde amnesia. Loss of consciousness was documented when an athlete was unresponsive to external stimuli and in paralytic coma as reported by teammates and/or on-field evaluation. By definition, athletes with LOC also had a concomitant PTA (ie, loss of memory for the duration of the unconscious state). For the purposes of this study, athletes with any degree of LOC were categorized in the positive LOC group. If the athlete sustained an additional period of PTA, they were also categorized in the positive PTA group.

High school and college athletes sustaining concussion from within the sample were referred for serial neuropsychologic evaluation after injury. Athletes were assessed within 24 hours of injury and at days 3, 5, and 7 after injury to determine "recovery curves" for both cognitive and self-report symptomatology. Concussion diagnoses and referrals were at the discretion of the respective athletic trainers or team physicians. A structured description of the concussive event was provided at the time of injury. Specifically, information was gathered about the nature of the "hit" as well as presence/duration of LOC, anterograde amnesia, retrograde amnesia, and posttraumatic confusion. The neuropsychologic tests and self-report inventory used in the postconcussion evaluation were identical to those used at the baseline evaluation. Available alternate forms of the HVLT and BVMT-R were administered to attempt to minimize the learning effects associated with the measures.

Control Subjects

College and high school athletes from the baseline sample served as control subjects. Control subjects were matched according to sport, age, high school grade point average (for high school athletes), college board examination scores (for college athletes), history of diagnosed learning disability, and history of previous concussion. Within the context of these criteria, it was possible for control subjects to be matched to more than one athlete with concussion. Control subjects for both high school and college samples were evaluated serially after their respective athletic seasons. No control subject had concussion during the course of the study.

Data Analysis

Data from all participating high school and college institutions were analyzed with Statistica, 5.1 statistical software for Windows (StatSoft, Tulsa, Okla). To allow an analysis of change in postconcussion test performance relative to baseline performance, a series of difference scores was calculated for each subject to reveal recovery (or lack thereof) compared with his or her own baseline performance. Scores were constructed so that a negative value signified a decline from baseline, whereas a positive number signified an improvement in performance from baseline. These change scores were calculated for the 24-hour postinjury period as well as for the 3-, 5-, and 7- day postinjury periods. Recovery patterns for the high school and college samples were compared with their respective control groups at each time after injury. A series of multiple analysis of variance analyses (MANOVA) was performed, with scores on standardized memory testing (difference scores) representing the dependent variables. For both the high school and college groups, the total words and delayed recall difference scores of the HVLT were used. At the high school level, the BVMT-R difference scores were also used as a dependent measure. These latter data are presented in this study, even though no direct comparison between high school and college athletes is possible.

RESULTS

Demographic Data

Of the high school sample, 95% was white (n = 37) and 5% was nonwhite (1 black and 1 Asian). At the college level, 66% were white (n = 35), 25% were black (n = 13), and 9% were of either Hispanic, Asian, or Polynesian ancestry (n = 5). In the high school sample, 90% (n = 35) of the athletes were football players and approximately 10% (n = 4) were soccer players. At the college level, 96% (n = 51) of the athletes were male football players and 2 (4% of sample) were female soccer players.

The mean age of the high school group was 15.9 years (range, 14-18 years), whereas the college sample had a mean age of 19.9 years (range, 17-25 years). The mean age differ-

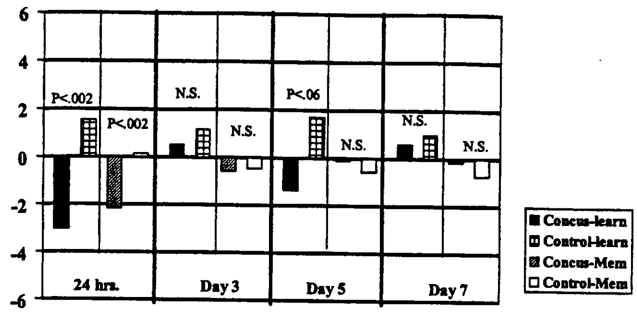

Fig 1. Recovery pattern of college athletes with concussion and control college athletes: Verbal learning and memory. Scores reflect mean difference of subjects relative to baseline performance. Lower score reflects poorer performance compared with baseline. Learning and memory scores represent performance on HVLT. *Concus-learn* indicates mean score for verbal learning for athletes with concussion; *Control-learn*, mean score for control athlete for verbal learning; *Concus-Mem*, mean score for verbal memory for athlete with concussion; *Control-Mem*, mean score for verbal memory for control athlete.

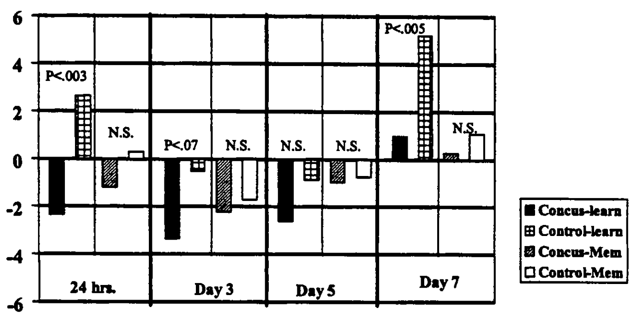

Fig 2. Recovery pattern of high school athletes with concussion and control high school athletes: Verbal learning and memory. Scores reflect mean difference of subjects relative to baseline performance. Lower score reflects poorer performance compared with baseline. Learning and memory scores represent performance on the HVLT. *Concus-learn* indicates mean score for verbal learning for athletes with concussion; *Control-learn*, mean score for verbal learning for control athletes; *Concus-Mem*, mean score for verbal memory for athletes with concussion; *Control-Mem*, mean control athlete score for verbal memory.

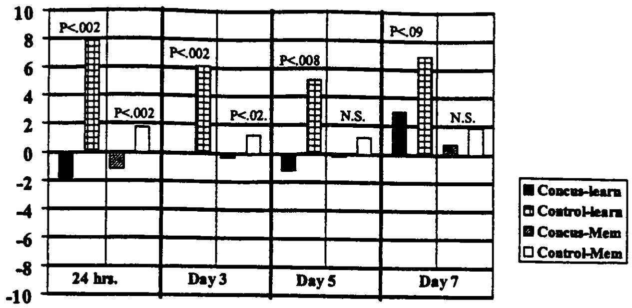

Fig 3. Recovery pattern of high school athletes with concussion and control high school athletes: Visual memory and learning. Scores reflect mean difference of subjects relative to baseline performance. Lower score reflects poorer performance compared with baseline. Learning and memory scores represent performance on the BVMT-R. *Concus-learn* indicates mean score for visual learning for athletes with concussion; *Control-learn*, mean score for visual learning for control athletes; *Concus-Mem*, mean score for visual memory for athletes with concussion; *Control-Mem*, mean score for visual memory for control athletes.

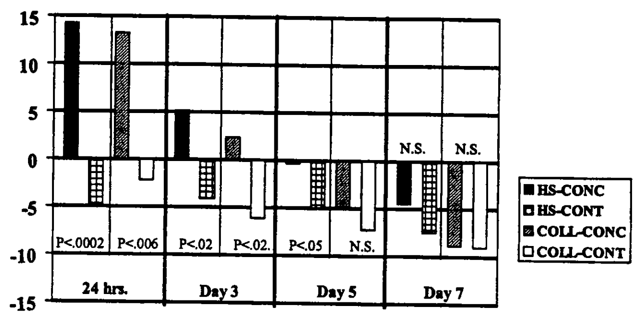

Fig 4. Symptom self-report of athletes with concussion and control athletes: High school and college. Scores reflect mean difference of subjects relative to baseline report of symptoms. Positive score reflects more symptoms compared with baseline on the Post-Concussion Scale-Revised. Negative score indicates less symptoms compared with baseline. *HS-CONC* indicates high school athletes with concussion; *HS-CONT*, control high school athletes; *COLL-CONC*, college athletes with concussion; *COLL-CONT*, control college athletes.

ence between these groups was statistically significant (P = .0001). The mean age of the pooled concussion group (18.4) was similar to the control group (18.3) (P = .961). The concussion and control groups did not differ significantly with regard to traditional achievement measures. At the high school level, grade point average (GPA) between the two groups was not significantly different (P = .10). Likewise, academic score differences between concussion and control groups at the college level were not significantly different (SAT scores [P = .70], ACT scores [P = .82], high school GPA [P = .50]).

The prevalence of learning disabilities (LD) in the study population was 5.4% (n = 5). There was no significant difference between the high school and college groups (P = .297). The concussion and control groups also did not differ significantly with regard to LD prevalence.

Prior Concussion History

Concussion history data were gathered at the baseline testing session with the use of a standard concussion history form; 53% of the pooled high school and college athletes in this study had a lifetime history of at least one prior concussion. The high school and college groups did not differ significantly with regard to their report of having one concussion in their past. The college group, however, reported a significantly higher rate of multiple concussions in their past (36% of college sample versus 7.7% of high school sample) (P = .002) and a significantly higher number of total concussions (P = .01) compared with the high school group. The severity of concussive events for both the high school and college groups generally fell within the mild range, with only 14 of 92 subjects (15%) reporting a history of LOC. The high school and college samples did not vary with regard to history of prior LOC.