# Neurocognitive Test Performance and Symptom Reporting in Cheerleaders with Concussions

Mark R. Lovell, PhD[1], and Gary S. Solomon, PhD[2]

**Objective** To evaluate neurocognitive test results and symptom reporting after sports-related concussion in a group of female cheerleaders.

**Study design** Junior and senior high school female cheerleaders (n = 138) underwent preparticipation baseline testing and repeated the ImPACT (Immediate Postconcussion Assessment and Cognitive Testing) evaluation within 7 days of concussive injury (range, 0-7 days; mean, 3.9 days). Postinjury neurocognitive and symptom scores were compared with preinjury (baseline) scores. "Abnormal" test performance was determined statistically using Reliable Change Index scores and self-reported symptoms. Main outcome variables included the composite scores indices from the ImPACT test, as well as symptoms reported by participants. Preinjury baseline and postinjury test results were compared using MANOVA.

**Results** As a group, cheerleaders with concussion evaluated within 7 days of injury performed poorly on the ImPACT test battery relative to their own baseline ($F = 6.5$; $P = .00$). In addition, 61% of the cheerleaders with concussions reported an increase in symptoms compared with baseline. The groups did not differ significantly by position on the squad ($F = 0.37$; $P = .96$). Of the group of cheerleaders who did not report increased symptoms at the time of postinjury evaluation, 37% had at least 1 abnormal ImPACT composite score result, suggesting some residual cognitive decline compared with baseline.

**Conclusion** The diagnosis and management of concussion in cheerleaders should not consist solely of self-reported symptoms. Neurocognitive test results represent an important component of the evaluation process and may identify athletes with residual neurocognitive deficits who report being clinically asymptomatic. *(J Pediatr 2013;163:1192-5)*.

Cheerleading carries the highest rate of catastrophic injury in sports, accounting for 66% of all catastrophic injuries in female athletes.[1] Mueller et al,[2] analyzing data from the Consumer Product Safety Commission, found that cheerleader injuries accounted for 4954 emergency department (ED) visits in 1980. The number of cheerleader-related ED visits rose continually, to 6911 in 1986, 16 982 in 1995, 22 603 in 2000, and 24 675 in 2002. In 2002, 351 of all ED visits (1.4%) were concussion-related.

Shields and Smith,[3] in a 1-year (2006-2007) prospective study of cheerleading-related injuries in the US, found that 6% of the total injuries were concussions, and that injuries tended to occur approximately 84% of the time in practices as opposed to games or during competition. Stunt and stunt-related injuries accounted for 96% of the concussions. In another study, Shields et al[4] found that stunt-related injuries accounted for 60% of the injuries, and that most injuries occurred while the cheerleader was basing or spotting for another participant. Lincoln et al,[5] in an 11-year prospective multiple-sport study of 25 high schools, found that 4.9% of reported concussions were incurred by cheerleaders.

In a study evaluating injuries in cheerleaders and level of participation, Boden et al[6] reviewed incidents of catastrophic cheerleader injuries reported to the National Center for Catastrophic Sports Injury between 1982 and 2002, and found that 29 of the 39 injured athletes were cheerleaders. That study suggested a higher rate of head injuries in collegiate cheerleaders compared with junior high and senior high school cheerleaders. The rate of injury in college cheerleaders was 5 times that in high school cheerleaders. Eighteen of the 27 reported catastrophic injuries involved head injury (66.67%), including 16 cases of cerebral edema or hematoma (89%), 13 skull fractures (72.22%), and 2 deaths.

The present study was designed to evaluate the "value added"[7] of neurocognitive testing in a group of cheerleaders as compared with symptom self-report alone. We hypothesized that the use of ImPACT (Immediate Postconcussion Assessment and Cognitive Testing)[8] computer-based neurocognitive testing would provide increased capacity to detect and measure postconcussive abnormalities in cheerleaders compared with symptom assessment alone. Furthermore, we

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| ED | Emergency department |
| ImPACT | Immediate Postconcussion Assessment and Cognitive Testing |
| PCS | Postconcussion Symptoms |
| RCI | Reliable Change Index |

From the [1]Department of Neurological Surgery, University of Pittsburgh, Pittsburgh, PA and [2]Department of Neurological Surgery and Vanderbilt Sports Concussion Center, Vanderbilt University School of Medicine, Nashville, TN

M.L. is the author of the ImPACT test, which was used as an outcome measure in this study. G.S. declares no conflict of interest.

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hypothesized that there would be no significant differences among spotters, bases, and flyers with regard to neurocognitive performance or symptom self-report.

## Methods

All participating institutions granted permission for their athletes' deidentified data to be used in this analysis, and Institutional Review Board approval was obtained for secondary analysis of deidentified data. All cheerleaders with concussion (n = 138) had undergone preseason baseline testing with ImPACT, completed at least 1 follow-up evaluation within 7 days of injury, and provided valid test results (as determined by multiple criteria provided automatically by the ImPACT test). Cheerleader position was based on athletes' self-report, which led to the classification into 3 groups: flyers, spotters/base positions, and participants who listed themselves as being "all-round" participants or "tumblers." Cheerleaders with a history of seizures, attention deficit-spectrum disorders, learning disability, psychiatric or chemical dependency disorder, autistic disorder, history of neurosurgical intervention, or any other known neurologic disorder were excluded from the analysis.

Concussion was broadly defined as a "traumatically induced alteration in mental status with or without a loss of consciousness."[9] In addition to altered consciousness, other typical symptoms of injury, including headache, dizziness, balance dysfunction, or nausea, after a blow to the head or body were classified as concussion. All injuries were identified as a concussion by a physician, athletic trainer, or other school health care official who was present at the time of the injury.

The ImPACT test battery was used in this study.[8] This computer-based neurocognitive assessment tool includes a demographic questionnaire, symptom inventory, injury evaluation form, and a 25-minute neurocognitive test battery. ImPACT was developed to allow completion of neurocognitive testing in an expeditious and standardized manner. Since its publication for clinical use in 1998, the ImPACT test battery has undergone extensive validation through multiple studies and is currently used throughout professional and amateur sports. The test-retest reliability of ImPACT has been demonstrated at intervals ranging from 1 week to 2 years.[10,11] Published research indicates that ImPACT is sensitive to the cognitive sequelae of concussion and is also able to separate athletes with and without concussions.[12,13] These studies have demonstrated good sensitivity and specificity in groups composed of athletes participating in multiple sports.

In addition to a standardized demographic questionnaire, the ImPACT test battery contains the 22-item Postconcussion Symptoms (PCS) scale. The PCS scale evaluates common postconcussive symptoms (eg, headache, nausea, dizziness, trouble sleeping) as rated by the athlete on a 7-point Likert scale ranging from 0 (asymptomatic) to 6 (highly symptomatic) according to his or her condition at the time of the testing session.[14]

The neurocognitive component of the ImPACT test battery evaluates multiple aspects of cognitive functioning, including attention, visual scanning, information processing, visual and verbal recognition memory, visual motor (processing) speed, and reaction time. ImPACT yields composite cognitive scores of verbal memory, visual memory, visual motor (processing) speed, and reaction time.

All of the data obtained from the administration process were automatically generated within the ImPACT clinical report and used in the present analysis. Significant declines in test scores after concussion and significant increases in symptom scores were identified by applying Reliable Change Index (RCI) scores as described by Schatz and Sandel[13] to adjust for practice effect and other factors that could possibly influence test scores over repeated testing. The RCI scores allow a clinician to account for measurement error surrounding test-retest difference scores and thus to adjust each score for practice effects secondary to multiple exposures to the particular test. For this study, RCI indices were established for the verbal memory (8.75 raw score points), visual memory (13.55 raw score points), reaction time (.06 raw score points), visual motor (processing) speed (4.98 raw score points), and total symptom (PCS) scores (9.18 raw score points) produced in the ImPACT report. These raw score point values result in a reliable change set at the 80% CI. An athlete's test performance was judged to be reliably different relative to his or her own baseline if the difference between postconcussion and baseline scores on a given composite index of ImPACT was larger than the established RCI value. Whenever an athlete exceeded these normal variations, he or she was considered abnormal on the test score in question.

Statistical differences in concussion classification using symptoms and ImPACT test results were determined by repeated-measures MANOVA. All statistical calculations were performed using Statistica (Statsoft, Tulsa, Oklahoma).

## Results

Characteristics of the sample (including age, position, and concussion history) are presented in the **Table**. Previously, cheerleaders with concussions did not differ significantly from cheerleaders with no history of previous concussion on ImPACT composite scores or the PCS score ($F = 0.70$; $P = .65$). Repeated-measures MANOVA was performed with position (flyer, base/spotter, other position) as the between-subjects variable and ImPACT composite scores (verbal memory, visual memory, visual motor/processing speed, reaction time) as the within-subjects factors. The impulse control composite is an index of test validity designed to identify athletes who produce suspect test results owing to suboptimal effort or failure to understand test directions. As mentioned previously, athletes producing invalid ImPACT results were excluded from the statistical analysis.

The MANOVA yielded no significant differences for the position variable ($F = 0.37$; $P = .96$), but did indicate a