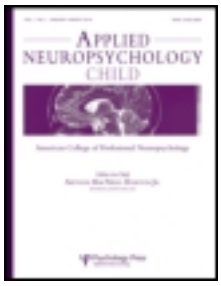

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Neurocognitive Functioning and Symptom Reporting of High School Athletes Following a Single Concussion

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The aim of this research was to evaluate the neurocognitive functioning and symptom reporting of high school athletes with the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery after sustaining a single sports-related concussion. The ImPACT battery was administered to 26 athletes at an average of 6.8 days after their head injury. ImPACT composite scores, including neurocognitive measures of Verbal Memory, Visual Memory, Processing Speed, and Reaction Time, as well as a Total Symptom Score, were also obtained from an equivalent group of 25 nonconcussed football players. The composite scores of the concussed athletes were lower but not statistically different than the nonconcussed athletes. The findings were consistent with previous ImPACT research that reported no differences between concussed and nonconcussed athletes 7 days after a concussion. The symptom scores of the concussed athletes, on the other hand, were significantly higher than those who had no concussion. The similarities and differences in ImPACT test performances of the present sample of concussed high school athletes as compared with previous studies of concussed high school athletes are discussed. This study raises awareness that with high school athletes, symptom complaints may persist, even after cognitive functioning has returned to preinjury levels.

Key words: *concussion, high school athletes, ImPACT, neurocognitive functioning, symptom reporting*

Sports-related mild traumatic brain injury (mTBI) or concussion has drawn increasing attention in recent years (Lovell, 2009; McCrory et al., 2009). At the high school level alone, about 62,000 varsity athletes sustain an mTBI annually, and of these, about 63% are football players (Powell & Barber-Foss, 1999). Epidemiological data indicate that the adolescent population has a higher incidence rate of football-related concussion compared with college players (Guskiewicz, Weaver, Padua, & Garrett, 2000). Concern about mTBI in adolescents is further heightened, with reports suggesting that children and youths aged 5 to 18 years old have the highest rates of sports and recreation-related TBI (Centers for Disease Control and Prevention, 2007). Moreover, high school athletes are at greater risk for concussions (Schulz et al., 2004) and have more persistent postconcussion neuropsychological sequelae than adults (Pellman, Lovell, Viano, &

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Casson, 2006). High school athletes appear to be particularly vulnerable to long-lasting neurocognitive effects following mTBI because of the continuous brain development process during the adolescent years (Patel, Shivdasani, & Baker, 2005).

The available studies regarding the neuropsychological effects of mTBI in high school sports have provided inconsistent results. Researchers using the Standardized Assessment of Concussion (SAC), a brief neurological and neuropsychological screening measure, found significant neurocognitive impairment in concussed high school and college football players 15 minutes after head injury, but nearly all of the 91 athletes displayed full recovery with the SAC within 2 days postinjury (McCrea, Kelly, Randolph, Cisler, & Berger, 2002). Investigators found a significant decline in neurocognitive functioning of high school athletes within 36 hours following a mild concussion, but the athletes returned to their baseline level of functioning by 6 days postinjury (Lovell, Collins, Iverson, Johnston, & Bradley, 2004). In a meta-analysis of 21 studies of sports-related concussion using high school athletes and beyond, no residual neuropsychological impairments were noted 7 days postinjury (Belanger & Vanderploeg, 2005).

In contrast, studies indicated that concussed high school athletes performed more poorly on memory tasks and reaction time (Field, Collins, Lovell, & Maroon, 2003; Pellman et al., 2006) and on measures of attention and concentration (Moser, Schatz, & Jordan, 2005) 7 days after their head injury compared with nonconcussed athletes. In a study that combined high school and collegiate athletes, researchers reported persisting verbal memory deficits that lasted at least 14 days postconcussion (McClincy, Lovell, Pardini, Collins, & Spore, 2006). Scores of visual memory, processing speed, and reaction time showed significant differences compared with their baseline levels at Day 7 but not at Day 14.

Research findings pertaining to postconcussion neurological symptoms have also been inconsistent. In some studies, high school athletes sustained mTBI symptoms such as headache, dizziness, and nausea that resolved at 4 to 6 days postinjury (Lovell et al., 2003, 2004). However, in other research, concussed high school athletes reported more neurological symptoms 7 days after their head injury compared with nonconcussed athletes (McClincy et al., 2006; Moser et al., 2005).

The purpose of this research was to examine further the neurocognitive functioning and symptom reporting of high school athletes using the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery, which has been employed in several previous studies regarding high school athletes following a concussion (Lovell, 2006).

METHOD

Test Instrument

In 1997, researchers began developing a neuropsychological assessment method initially at Detroit's Henry Ford Health System and later at the University of Pittsburgh Medical Center as part of their work with the Pittsburgh Steelers football team concussion program. The collaborative effort resulted in a computerized neuropsychological test battery, the ImPACT, which evaluates verbal and visual memory, processing speed, reaction time, and impulse control (Maroon et al., 2000). ImPACT provides a relatively brief (20 to 30 minutes), cost-efficient evaluation with clinically useful information for the management of head-injured athletes. Research during the past decade has found that ImPACT is a reliable, sensitive, and practical approach to the neuropsychological assessment of mTBI in high school and collegiate athletes (Lovell et al., 2003; McClincy et al., 2006; Schatz, Pardini, Lovell, Collins, & Podell, 2006).

Currently, ImPACT is utilized by more than 1,300 colleges and more than 3,500 high schools across the country, as well as 21 National Football League teams, all National Hockey League teams, 32 Major League Baseball teams, 18 Major League Soccer teams, 8 National Basketball Association teams, 25 professional rugby teams, 5 Olympic sports, and professional motor sports teams (Lovell, 2006).

Version 3.0 of ImPACT consists of six individual test modules that measure different neurocognitive abilities. The four standard ImPACT composite scores used for this research were Verbal Memory, Visual Memory, Processing Speed, and Reaction Time. ImPACT also included the Post-Concussion Symptom Scale, which consists of 22 commonly reported symptoms (e.g., headache, dizziness) and yields a Total Symptom Score. Impulse Control scores were not utilized based on prior studies that suggested they do not discriminate between concussed and nonconcussed high school athletes.

Participants

A retrospective archival search consisting of 56 high school athletes who were administered the ImPACT yielded the ImPACT test results of all athletes who sustained a recent single concussion ($n=26$) and who were tested at an average of 6.8 days ($SD=5.12$) after their head injury. This was the only postinjury assessment for these athletes. Concussion was diagnosed by a certified athletic trainer using the standard American Academy of Neurology (1997) nomenclature. The sports represented were football, soccer, wrestling, basketball, softball, judo, lacrosse, and cheerleading.

At this high school, only football players were tested for baseline levels prior to their season. Among the 30 football players, the study excluded 3 who had a concussion in a previous season. Two of the youngest athletes were also excluded to obtain age equivalency between the concussed and nonconcussed athletes. Thus, this study utilized 25 athletes who had no prior history of concussion to form a nonconcussed comparison group.

The average age of the total sample was 15.20 years (SD=1.73). Participants had completed an average of 10.04 years of education (SD=1.40).

The high school was located in Honolulu, HI, with the ethnic composition of the sample including 16 Asians, 8 Caucasians, 5 Pacific Islanders, and 22 Mixed Ethnicities.

Procedure

The nonconcussed participants were administered the ImPACT prior to their 2009 football season to establish baseline or preinjury neuropsychological test data that would be used in making return-to-play decisions if the athlete incurred a sports-related concussion. The concussed participants did not have baseline testing and were tested with ImPACT only after a closed-head injury. ImPACT was administered to each athlete supervised by an athletic trainer.

RESULTS

Data pertaining to demographic variables are provided in Table 1. Analysis of the demographic variables established between-group equivalency, with no significant differences noted between the concussed and nonconcussed groups on age, education, and years of experience in playing the sport.

The means and standard deviations of the ImPACT composite scores and the Total Symptom Score are presented in Table 2. Analysis by t-tests revealed no differences between the concussed and nonconcussed groups on the four composite scores but found the Total Symptom Score to be significantly higher in the concussed athletes (M=12.85, SD=13.20) as compared with nonconcussed athletes (M=2.40, SD=3.56). Cohen's d for the Total Symptom Score differences revealed a large effect size (d=1.08).

TABLE 1
Demographic Data for the Concussed and Nonconcussed Groups

	Concussed (n=26)		*Nonconcussed (n=25)*			
	M	*SD*	*M*	*SD*	*t*	*p*
Age	15.42	1.30	15.20	1.73	–0.52	.60
Education	9.23	1.31	9.04	1.40	–0.50	.62
Years experience	1.62	1.11	1.64	1.11	0.08	.94

TABLE 2
ImPACT Scores of the Concussed and Nonconcussed Groups

	Concussed (n=26)		*Nonconcussed (n=25)*				
	M	*SD*	*M*	*SD*	*t*	*p*	*d*
Verbal Memory	81.19	12.59	85.12	11.13	1.18	.24	0.33
Visual Memory	66.81	15.20	72.76	14.84	1.41	.16	0.40
Processing Speed	39.14	6.50	38.01	6.50	–0.62	.54	0.17
Reaction Time	2.62	10.48	0.55	0.06	–0.99	.33	0.28
Total Symptom	12.85	13.20	2.40	3.56	–3.82	.00	1.08

DISCUSSION

The present study found that the neuropsychological functioning of multiethnic high school athletes who sustained a single concussion, when tested 7 days after their head injury, was lower but not significantly different than that of their counterparts who had no history of concussion. The results were consistent with a previous study of concussed high school athletes who performed similarly to nonconcussed athletes 1 week after their head injury on the ImPACT test battery (Lovell et al., 2004). Likewise, a meta-analysis of 21 studies involving primarily high school athletes found no residual neuropsychological impairment when testing was completed beyond 7 days postconcussion (Belanger & Vanderploeg, 2005).

Previous research found significant differences between concussed and nonconcussed high school athletes 7 days postinjury on neurocognitive measures and on a postconcussion symptom scale (McClincy et al., 2006; Moser et al., 2005). However, in this study, no differences in neuropsychological test scores were noted between the concussed and nonconcussed athletes, while substantial differences were found in the ImPACT Total Symptom scores.

An earlier study revealed that high school athletes with concussion reported significant postconcussive symptoms 5 days after injury, while concussed athletes at the college level reported significant postconcussive symptoms at Day 3 but not at Day 5 (Field et al., 2003). The authors suggested that high school athletes may demonstrate more protracted recovery from concussion than college athletes. Conferees who developed the 2008 Consensus Statement on Concussion in Sport also recognized the longer time frame for symptom recovery by

adolescent athletes and called for a more conservative return-to-play approach (McCrory et al., 2009).

One of the strengths of this study was the identification of concussion by a certified athletic trainer utilizing the standard American Academy of Neurology (1997) criteria rather than relying on the nonverifiable self-reports of a concussion by high school athletes.

The limitations of the present investigation are worthy of note. The small sample size of concussed athletes limited the power of the statistical analyses and lowered the ability to reject the null hypothesis. The concussed athletes, tested about 7 days postinjury, displayed no significant differences in their neurocognitive test scores than the nonconcussed athletes. Higher statistical power may have led to results comparable to previous studies that found substantial neuropsychological deficits 7 days after their mTBI (Field et al., 2003; McClincy et al., 2006; Moser et al., 2005). The ethnic makeup of this research sample was uniquely different than in earlier studies, but the small sample sizes precluded any conclusions being drawn about possible sociocultural influences on the results. The investigation of the effect of cultural factors on the neuropsychological test performances of school athletes was recommended by a 1997 panel of neurologists and psychologists addressing issues in sports-related concussion (Lovell & Collins, 1998).

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