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The Importance of Proper Administration and Interpretation of Neuropsychological Baseline and Postconcussion Computerized Testing

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Media coverage, litigation, and new legislation have resulted in a heightened awareness of the prevalence of sports concussion in both adult and youth athletes. Baseline and postconcussion testing is now commonly used for the assessment and management of sports-related concussion in schools and in youth sports leagues. With increased use of computerized neurocognitive sports concussion testing, there is a need for standards for proper administration and interpretation. To date, there has been a lack of standardized procedures by which assessments are administered. More specifically, individuals who are not properly trained often interpret test results, and their methods of interpretation vary considerably. The purpose of this article is to outline factors affecting the validity of test results, to provide examples of misuse and misinterpretation of test results, and to communicate the need to administer testing in the most effective and useful manner. An increase in the quality of test administration and application may serve to decrease the prevalence of invalid test results and increase the accuracy and utility of baseline test results if an athlete sustains a concussion. Standards for test use should model the American Psychological Association and Centers for Disease Control and Prevention guidelines, as well as the recent findings of the joint position paper on computerized neuropsychological assessment devices.

Key words: concussion assessment and management, mild traumatic brain injury, sports-related concussion

THE CALL FOR CONCUSSION TESTING

Media coverage, litigation, and new legislation have resulted in a heightened awareness of the prevalence of sports concussion in both adult and youth athletes. The Centers for Disease Control and Prevention (CDC) report an incidence ranging from 1.3 million to 3.8 million head injuries per year, with approximately 300,000 being sports-related (CDC, 2012). This growing problem is exemplified by the fact that from 1997 to 2007, the number of children treated for concussions in emergency departments doubled (CDC, 2010). At the time of the publication of this paper, 49 states and the District of Columbia in the U.S. have passed some type of legislation

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that addresses the need for concussion awareness and management in schools (see Moser, 2012). The prevalence of youth sports concussions is now considered to be at "epidemic" levels (Udall, 2012).

Along with the media and regulatory attention during the last decade, there has been an increase in research on the deleterious effects of mild head injuries, particularly those occurring during contact sports. Many of these studies have indicated that there are not only short-term physiological, cognitive, and emotional changes that arise postinjury (Belanger & Vanderploeg, 2005), but these issues do not always resolve and result in long-term difficulties. In some cases, postconcussion syndrome may occur, in which the symptoms of the head injury have not resolved by 3 months postinjury (Jotwani & Harmon, 2010). Additionally, researchers have demonstrated that multiple concussions may lengthen patient recovery time and increase the severity of symptom presentation (Collins et al., 1999; Moser, Schatz, & Jordan, 2005). The recent increase in legislative actions aimed at protecting athletes from the possible hazards of concussion in school, recreational, and club sport has resulted in organizations arranging to provide concussion management programs for their youth athletes (Mayo Clinic, 2012; Simovska, 2012). For many, part of that programming includes the implementation of baseline and postconcussion neuropsychological testing programs. The purpose of this article is to outline factors affecting the validity of test results and to provide examples of misuse and misinterpretation of test results. Additionally, we intend to provide recommendations regarding standards that can be adopted to promote appropriate and careful testing practices while also minimizing misuse.

BASELINE AND POSTCONCUSSION TESTING

Typically, the paradigm for baseline and postconcussion testing arose in the 1980s with college athletes (Barth et al., 1989) and has now extended to most professional and amateur-level sports. The athlete undergoes a short battery of neuropsychological tests in the preseason, prior to contact risk and concussion, and testing is repeated after a concussion has been sustained. Comparison of baseline to postconcussion test results can provide valuable information to assist in the decision as to when the athlete may have recovered from his or her brain injury. Over the years, a number of different computerized test batteries have been developed to measure behavioral constructs commonly affected by concussion, such as verbal memory, visual memory, attention, mental speed, reaction time, and physical/emotional/cognitive/sleep symptoms (Kontos et al., 2012; Lovell & Collins, 1998; Maroon et al., 2000).

Importantly, the neuropsychological test is just one piece of information in the decision-making process of deciding when an athlete is ready to return to play. Other information sources, such as clinical examination, medical/academic/psychological history, patient report, observer report, balance assessment, and athletic exertion testing, should also be considered in the treatment and recovery plan (McCrory et al., 2009). Neuroradiological measures such as computed tomography and magnetic resonance imaging generally lack sensitivity and diagnostic utility in the acute stages of concussion (McCrory et al., 2013), and computer-based assessments have been shown to be more sensitive to acute effects of concussion compared with paper-based measures (Broglio, Macciocchi, & Ferrara, 2007). In addition, the utility of neuropsychological testing has been demonstrated and shown to be of significant added value in the diagnostic process, even when athletes claim to be symptom-free (Van Kampen, Lovell, Pardini, Collins, & Fu, 2006).

Computerized concussion testing has been utilized since the 1990s in professional sports and most recently has become more commonplace in schools across the nation. Currently, the Immediate Postconcussion Assessment and Cognitive Testing (ImPACT; Lovell, 2007) is widely used among the growing number of computerized concussion tests, which also include Axon, Headminder (Erlanger, Feldman, & Kutner, 1999), and Concussion Vital Signs (CNS Vital Signs, LLC, 2012). The ease of computerized testing has been lauded as a way of bringing concussion testing services to the masses in a relatively inexpensive mode of outreach (Schatz & Zillmer, 2003). Groups of athletes can be simultaneously tested in school computer labs or similar setups, therefore reducing the time and personnel needed, compared with a "typical" neuropsychological testing, which involves one-on-one interaction with a neuropsychologist or psychometrist and a longer and more comprehensive assessment (e.g., integration of test results with clinical history, behavioral observations, personality assessment). In fact, on its Website, ImPACT notes that testing in groups of 10 to 15 athletes is "optimal" for baseline administration (ImPACT, 2012).

The growth of computer-based testing has also created a lack of clarity regarding what differentiates a cognitive "screening" measure from a "neurocognitive assessment" from a "neuropsychological assessment." The most recent "consensus expert" statement from the Concussion in Sports Group describes "brief neuropsychological test batteries" as assessing attention and memory function and as being designed for "rapid screening" and "not meant to replace comprehensive neuropsychological testing" (McCrory et al., 2013, p. 7). In contrast, the most recent Sports Concussion Guideline from the American Academy of Neurology describes a variety of diagnostic tools suitable for aiding in the detection/diagnosis of concussion but only differentiates two types of

neuropsychological testing instruments: paper-based and computer-based (Giza et al., 2013). The administration of neuropsychological test measures by non-neuropsychologist sports medicine personnel has previously been supported in these consensus expert statements, suggesting that computer-based neurocognitive tests can be administered by a team physician, or be Web-based, thus bypassing the need for formal assessment by a neuropsychologist (Aubry et al., 2002; McCrory et al., 2004). In a joint paper from the American Academy of Clinical Neuropsychology and the National Academy of Neuropsychology, the distinction was made between neuropsychological "testing" (e.g., obtaining behavioral samples of abilities in specific areas) and "assessment" (e.g., a comprehensive evaluation that integrates test results from a variety of domains; Bauer et al., 2012). However, neuropsychologists, by virtue of their background and training, are identified as being "in the best position" to *interpret* neuropsychological tests (McCrory et al., 2009, 2013). In this regard, neuropsychologists are uniquely qualified to translate test data into recommendations for clinical management (Moser et al., 2007), a sentiment supported by Echemendia and colleagues (Echemendia, Herring, & Bailes, 2009) who describe baseline testing as a "technical procedure" that can be conducted by technicians (supervised or guided by neuropsychologists), whereas postinjury neuropsychological assessment should be conducted by an individual with "advanced neuropsychological expertise" and is thus best conducted by a clinical neuropsychologist.

THE CALL FOR PROPER TEST USE

Recently, a joint position paper of the American Academy of Clinical Neuropsychology and the National Academy of Neuropsychology discussed the problems with computerized neuropsychological assessment devices in the areas of marketing, administration/interpretation, technical issues, privacy/data security, and reliability/validity, as well as factors affecting examinee performance, reporting services, and the need to check for validity and effort (Bauer et al., 2012). The authors expressed "the need to ensure that such tests are developed and utilized competently, appropriately, and with due concern for patient welfare and quality of care" (Bauer et al., 2012, p. 362).

The American Psychological Association (APA) has regulated the development, administration, interpretation, and use of neuropsychological and psychological tests (APA, 1999). More specifically, the APA provides lengthy and detailed standards to protect the public from test misuse and unethical activities. Tests must be considered valid and reliable tools to most effectively serve their purpose. For that to occur, they are researched, normed, and validated in a scientific manner. Standardized administration procedures are created and applied as part of the validation and norming process. The distribution of such tests is monitored so that only authorized, trained individuals use them and so that they are administered in a controlled manner to be sure that they are really testing what they claim to be testing.

It is for this reason that the SATs (once known as the Scholastic Aptitude or Scholastic Achievement Tests), which are used for college admission applications (www.collegeboard.com), are not given to students as take-home tests. Without supervision and standardized, controlled test environments, the validity of the test results could be jeopardized by those who might complete it as an open-book test, have someone else take it for them, or copy test items for others to practice prior to taking the test in the future. Also, if the testing environment is not controlled (e.g., kept quiet and orderly), environmental distraction may negatively affect test takers' ability to concentrate and perform optimally. In such cases, the test results would not accurately represent the true skills of the individual and would therefore compromise the utility of the test scores. Given the seriousness of college entrance decisions, educational facilities that administer and use these tests are held to rigid standards for controlled, standardized administration. In fact, test administrators need to undergo training and certification by the College Board (www.collegeboard.com).

With what appears to be in the spirit of "good intentions," schools and other organized sports organizations have begun purchasing and using these testing programs, sometimes without fully understanding the tools or the testing process. However, these are neuropsychological tests that are not intended for use by untrained individuals. Even when a test manufacturer advises that tests are only to be used by "trained professionals," it is unclear how this is defined or protected. While licensed psychologists are expected to "provide services … in areas only within the boundaries of their competence, based on their education, training, supervised experience, consultation, study or professional experience" (APA, 2010, p. 4) it is not clear if simply completing a lone online course on concussion would qualify one as a "trained professional." Anecdotally, within the past year, one of the present authors received a phone call from a physician's office manager requesting a recommendation of an online course the physician could complete, because he was to begin providing concussion services to a school district, which requested documentation of such training. It appears the physician thought such a course would qualify him to contract with the school district to provide concussion services. Such occurrences have led some groups, like local brain injury associations, to draft guidelines, referral lists, and brochures that include what to look for in a concussion specialist.

With regard to test administration, the CDC has declared: "baseline tests should only be conducted by a trained health care professional" (CDC, 2010, p. 1). In addition, the CDC states that baseline tests should only be interpreted by trained health care professionals with experience in concussion management. The notion that a neuropsychologist should interpret computerized or paper-and-pencil neuropsychological test components of a baseline exam is shared by others (Echemendia et al., 2009).

Unfortunately, inadequately trained or untrained individuals often administer or direct sports concussion management programs. In a 2009 study, 87.5% of athletic trainers surveyed reported administering computer-based neuropsychological tests, 18% reported being solely responsible for interpreting test scores, and 10% reported they would return an athlete to play who is symptom-free but who scores below baseline levels (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). Further, these individuals may neither fully understand the proper standardized test administration procedures nor the individual and environmental factors that may affect testing or test results. This may be due to a number of factors, including: (a) a limited understanding of the need for collaboration with individuals trained in brain–behavior relationships, (b) a limited understanding of test administration procedures, and/or (c) a lack of funds or resources to hire or train personnel or to provide adequate space and technological support. Realistically, many high schools and sports organizations neither have access to a certified athletic trainer (National Athletic Trainers' Association [NATA], 2012) nor have personnel with the expertise to identify suspect test results, interpret them, and know how to intervene. And certainly, these organizations do not have skilled brain–behavior specialists or neuropsychologists on staff.

We propose that any excuse of lack of resources, personnel, or funding is not a sufficient justification for implementing a concussion management program for youth in a suboptimal fashion, wherein test results may be not be reliable or valid for many of the athletes. Importantly, the value of baseline and postconcussion testing is not in question. Rather, it is vital such testing programs be implemented in the most effective and useful manner. Doing so may actually decrease test score invalidity and increase the accuracy and utility of baseline and postconcussion test scores if an athlete sustains a concussion.

COMMON PROBLEMS IN THE USE OF BASELINE AND POSTCONCUSSION TESTING

As with many revolutionary advances, use of new technology may have preceded its control and regulation. Such evidence can be seen in the early American promotion of a variety of elixirs that were later regulated through the development of the U.S. Food and Drug Administration (2012) and electronic communication of health information that is now regulated by the Health Insurance Portability and Accountability Act (U.S. Congress, 1996). With the evolution of concussion testing and our increased scientific knowledge of the injury, the time has now come for the use of computerized baseline and postconcussion testing to come under scrutiny and appropriate regulation.

With the introduction of concussion testing programs in schools, much of the burden of execution and implementation has unfortunately come under the control or supervisory duties of certified athletic trainers (Meehan, d'Hemecourt, Collins, & Comstock, 2011). This, at first, may seem counterintuitive because the tests themselves are neuropsychological in nature and require an understanding of brain–behavior relationships and expertise in mild traumatic brain injury diagnosis. Furthermore, cognitive tests are usually administered by neuropsychologists, psychologists, or trained educational and cognitive specialists, such as speech-language pathologists. However, as these testing programs directly address athletes, and because their most visible use has been in professional sports, they understandably became housed and maintained by athletic health care staff. Yet, even within professional sports, neuropsychologists historically maintained (and continue to maintain) oversight of testing, while working with athletic trainers and sports physicians in the program implementation and test results interpretation (Webbe, 2010). For example, the National Hockey League's concussion testing program is managed by a network of neuropsychologists, who execute a well-designated protocol of testing. Team trainers and physicians provide immediate triage and treatment of concussions, and the neuropsychologists in the "home" city conduct testing, thus controlling the timing of testing, the tests used, and the personnel administering and interpreting the test results.

When schools began adopting concussion programs, these tests immediately fell under the auspices of the athletic department. Unfortunately, as previously mentioned, only 42% of schools in the United States have athletic trainers (NATA, 2012). School districts do not typically hire neuropsychologists, but rather employ school psychologists and other child study team specialists, who are not systematically trained in youth concussion (Moser, 2007). Not surprisingly, the task of test administration is often "turfed" to other unprepared individuals, such as the school nurse, or even the parent at home (Moser, 2012). The problem is compounded in organized community and club sports where there are traditionally no health care personnel or certified athletic trainers and those in charge are more often volunteers with limited exposure to

concussion education. Considering the necessary resources and strict regulations/guidelines required for standardized educational testing in schools, it seems surprising that similar controls are not in place for cognitive testing surrounding brain injuries.

Concussion testing programs are often implemented with limited staff support and training. As a result, there are a number of irregularities that can occur (and have occurred), in which the integrity and validity of the baseline/postconcussion test administration and interpretation have been threatened: (a) Baseline test results are not always checked for validity as they are directly stored in the computer/server database and staff often do not have the time to retrieve and check each student's results (Covassin, Elbin, & Stiller-Ostrowski, 2009); (b) often only selected groups of athletes are tested such as varsity teams or athletes in the more high-risk collision sports (Putukian, Aubry, & McCrory, 2009); (c) supervision of test administration is lacking, providing the opportunity for cheating; (d) test administration directions are often overlooked, such as when athletes are permitted to take the test after they have just come from heavy exertion or athletic practice; (e) environmental test conditions are not consistently controlled for distractions that interfere with test performance; (f) athletes' understanding of the test, or their reading ability, or their effort during testing is not uniformly monitored; and (g) not all athletes are tested before the athletic season starts.

Following are some real-life examples that have been reported in sports concussion practices:

1. A parent reported that her son was asked by the school to complete his baseline test at home. He did so, but in the family room, where the home computer is located, and where there was much family traffic and distraction.
2. A youth athlete admitted that another athlete completed the baseline assessment for her.
3. A youth patient who had sustained a concussion reported that at her school, students complete baseline tests without supervision and often copy the test items onto paper and distribute them to other students before they take their baseline test.
4. On one of the memory subtests of the computerized concussion test battery, the athlete "traced" with his smudged fingers on the computer screen the letters he was supposed to later remember for the memory task.
5. Several concussed youth athletes presented in clinic for postconcussion examination with baseline test results from their schools or organizations that could not be utilized because they were invalid. This invalidity was not discovered; because the baseline test results were never initially reviewed for validity by those who administered the testing, the athletes were not readministered a baseline assessment. Some reasons for these invalid results included:
   a. The athlete was ill on the day of baseline assessment and no one noticed that the baseline scores were significantly low or that the symptom score was uncharacteristically high.
   b. The athlete was fatigued because the baseline test was completed immediately after an athletic practice, negatively affecting performance.
   c. The athlete had a reading disorder (or in another case was a young, weak reader aged 10 to 12 years old) and did not understand the directions (or specific vocabulary in the directions) prior to beginning the test sections.
   d. The athlete was told by his parent to "do his best" and "take his time to get every answer right," which caused him to proceed slowly and carefully, thus producing poor speed scores that were not reflective of his true ability.
   e. The athlete attempted to "sandbag" or intentionally perform poorly on the baseline, which was never caught by the athletic trainer who administered the test.
   f. The athlete admitted that she did not take the baseline test seriously, and quickly completed the assessment in order to be permitted to begin preseason practices.
   g. The Impulse Control score (on ImPACT) was greater than 30, indicating suspect validity, yet no one inspected or otherwise reviewed the baseline test results.
6. A school athletic trainer, untrained in how to interpret postconcussion test results, managed a concussed athlete by requiring numerous (and unnecessary) reassessments while the athlete was becoming increasingly symptomatic. Despite decreasing test scores, the athletic trainer allowed the athlete to attend gym class, where the concussed athlete was subsequently hit in the head with a ball.
7. A school principal had pressured the school athletic trainer to make return-to-play decisions without consulting a physician or neuropsychologist in order to save on assessment costs for the school.
8. A school nurse had been pressured by a parent to administer and interpret neurocognitive testing for an athlete who was concussed as a result of a motor vehicle accident.

These and other similar situations of mishandling and misuse point to an existing cavalier attitude toward, and

disregard of, the seriousness of computerized neurocognitive testing. Furthermore, interpretation of baseline and postconcussion test results requires expertise in brain function and behavior, as well as knowledge of the tests used and the various factors that may affect test scores. Preexisting emotional and psychological factors, as well as cognitive factors, such as attentional and learning disorders (which are sometimes not yet diagnosed in an athlete), can also impact how one interprets both baseline and postconcussion test findings. Without knowledge and consideration of the effect of these factors, misinterpretation and/or misuse of baseline and postconcussion test results can occur (McCrory et al., 2009).

CONSIDERATIONS

With these issues in mind, the time is long overdue for the proper regulation of baseline and postconcussion testing. This may mean an approach that takes us back to square one: implementing a logical, standardized testing administration procedure as is already performed in schools with standardized testing. Whether in a group (as with the SATs) or individual testing situation (as with child study team evaluations), a controlled environment and a standardized protocol are expected (Moser, Schatz, Neidzwski, & Ott, 2011). The critical factors to ensure best baseline testing practices are: (a) Test administration is taken seriously by both the examiners and examinees; (b) all parties involved in the assessment process understand the purpose of the test and its uses; (c) examinees understand test directions; (d) the environment is quiet, controlled, and free of distractors; (e) supervision is tight with safeguards to prevent cheating and to protect the integrity of the test and test results; (f) qualified trained professionals review test results for validity and interpretation; and (g) proper, reliable, and well-functioning equipment is used.

Research has shown that groups of athletes completing baseline testing were found to exhibit a higher rate of invalid results compared with athletes completing baseline testing in an individual setting (Moser et al., 2011). This is not surprising as individual testing is generally conducted in an environment that may provide greater supervision, increased control on the part of the examiner, and less opportunity for distraction from other individuals in the room. Such a finding is important because postconcussion testing is commonly performed individually, with the goal of testing the athlete in an environment that minimizes distraction; of course, simply testing in an individual setting may not equate to a distraction-free environment. Yet, comparing group baseline test results to individual postconcussion test results may be risky. Future research may well focus on how to improve the level of supervision, control, and motivation in the group-testing setting so as to reduce the prevalence of invalid test results. On an encouraging note, some of these computerized test assessment tools are beginning to address these issues surrounding group test administration and including specific instructions on how to control the environment for distractions and prepare students to take the tests seriously.

Perhaps it may be worth considering that schools and organizations become qualified as baseline and postconcussion testing sites similar to how testing sites are certified by the College Board for the SATs. Another alternative currently being employed is that of designating a neuropsychologist, school psychologist, or other cognitive/learning specialist with expertise in sports concussion management to manage and oversee these testing programs. Unfortunately, neuropsychologists are not often available to serve as consultants in rural areas (Guskiewicz et al., 2004).

CONCLUSIONS

There are no shortcuts to providing sports concussion services. The management of these injuries requires working with a collaborative team of specialists such as athletic trainers, neuropsychologists, neurologists, sports physicians, and others with sports concussion expertise. Unfortunately, most physicians, whether primary care, pediatric, neurologic, or otherwise, do not presently have adequate training or infrastructure to systematically diagnose and manage concussed athletes (Zonfrillo et al., 2012), which has prompted state legislation, the CDC, and other groups to encourage continuing education in this area. In fact, medical students and residents report having incomplete knowledge about concussion diagnosis and management (Boggild & Tator, 2012). Currently, there is limited knowledge and understanding of the importance of standardized and controlled testing environments and procedures among the groups who are purchasing and administering these tests to youth. Tests administered under noisy conditions, in unsupervised settings, without educating test takers as to the importance and seriousness of concussion testing ultimately decrease the utility and validity of the test results.

It is time for a wake-up call: There should be no excuses (e.g., lack of resources, funding, or staff) for the current level of computerized, neurocognitive test misuse. These concussion tests should be administered with the same care and consideration afforded all standardized neuropsychological and educational tests. Baseline and postconcussion testing programs, test developers, and test vendors must be required to demonstrate proper concern and respect for testing standards, such as those already promulgated by the APA, which provide for reliable, valid, interpretable test results that protect, benefit, and respect the welfare of the patient and in this case the athlete.

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