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# Sports Neuropsychology With Diverse Athlete Populations: Contemporary Findings and Special Considerations

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This paper aims to familiarize readers with the contemporary scientific literature available on sports concussion as it relates to populations divergent from adult males who play football and hockey. Herein, we focus on important issues such as age, gender, culture, language, sport type, and premorbid conditions (such as learning disabilities [LD] and attention deficit/hyperactive disorder [ADHD]) that can influence concussion incidence, severity, and recovery.

**Keywords:** Concussion, Traumatic Brain Injury, Sport, Diversity, Neuropsychology

The historic and current literature on sports-related concussion has predominantly focused on American football. The reasons for this focus are both simple and understandable:

- The seminal study on sport-related concussion by Barth and colleagues in 1989 occurred within a study of college football players.
- Football teams represent the largest rosters of participants across sports.
- Collisions involving the head occur on every play in football.
- Injuries of the head, especially, galvanized President Theodore Roosevelt to threaten a ban on football in the early 1900s (which spurred the creation of the National Collegiate Athletic Association, NCAA).
- Professional and now many college/university football teams participate in concussion management programs for athlete protection—programs that easily translate into research studies.

This focus on football has subsequently resulted in the study of primarily of adult, male American athletes (mostly Caucasian and African Americans), since

they are the predominant participants at the collegiate and professional levels. Yet, football is certainly not the only sport where concussions frequently occur. A succession of epidemiological studies over the past 15 years has shown concussions occur in other sports with equivalent or greater frequency than in football, and participants in these other sports include women and individuals from other national, ethnic, and cultural groups (Dick, 2009; Gessel, Fields, Collins, Dick, & Comstock, 2007; Hootman, Dick, & Agel, 2007). Moreover, in addition to the young, male adults mostly studied within the football contexts, many more of the world's youth participate in sports where the risk of concussion is moderate to high.

The epidemiology and consequences of concussion have been well documented at the professional level, particularly within the NFL and NHL, making this a hot issue not only within the sports medicine community, but also in the public media (Benson, Meeuwisse, Rizos, Kang, & Burke, 2011; Pellman et al., 2004). Notably, computerized neuropsychological batteries such as ImPACT, HeadMinder, and CogSport have been reported to have a high degree of sensitivity to cognitive changes postconcussion (Collie et al., 2003; Erlanger et al., 2003; Schatz, Pardini, Lovell, Collins, & Podell, 2006). The specialized knowledge base that neuropsychologists have with regard to brain-behavior relations along with these clinical tools have placed neuropsychologists in a key role of evaluating and managing concussed athletes and has led to a surge of empirical investigations in the last decade (Lovell, Collins, Iverson, Johnston, & Bradley, 2004; McCrea et al., 2003). The accumulation of evidence along with highly publicized cases supporting the potential for dangerous and even lethal outcomes, such as the controversial Second Impact Syndrome (Cantu & Voy, 1995) and Chronic Traumatic Encephalopathy (McKee et al., 2009) as well as cumulative cognitive effects of multiple concussions (Guskiewicz et al., 2003), have led to a series of international conventions on sports concussion management (McCrory et al., 2009; McCrory et al., 2005; Aubry et al., 2002). This increased awareness and vigilance has led to improved protective equipment, the establishment of concussion management programs at all levels around the United States, and legislation in several states that mandates concussed athletes to seek medical attention by healthcare personnel (including neuropsychologists). State regulations related to mandatory helmet use have also been passed with the aid of neuropsychologists' advocacy efforts. Despite the provision of these measures, many individuals responsible for caring for athletes (particularly in the pediatric domain) are not uniformly familiar with guidelines for the identification, treatment, and management of concussions. The current standard of practice is that an individualized approach should dictate return-to-play decisions rather than "cookie cutter" guidelines based on previous grading scales or the simple vs. complex definition of concussion, which seemed arbitrary in nature (Halstead, Walter, & The Council on Sports Medicine and Fitness, 2010).

## Purpose

In light of these standards, the purpose of the present paper is to familiarize readers with the contemporary scientific literature available on sports concussion as it relates to populations divergent from adult football (and hockey) playing males. We herein focus on issues of age, gender, culture, language, and premorbid condi-

tions, such as learning disabilities (LD) and attention deficit/hyperactive disorder (ADHD) that can influence concussion incidence, severity, and recovery.

### **Risk Factors in Youth: Is Age Really Nothing but a Number?**

Although concussions can lead to negative consequences in athletes at all levels of sport, there are several reasons to believe that youth may represent a particularly vulnerable population. First, it has been reported that high school athletes sustain concussions more frequently than collegiate athletes participating in the same sport (Barth et al., 1989; Guskiewicz, Weaver, Padua, & Garrett, 2000). This does not account for the many undetected and unmanaged injuries that occur, and we could not find any studies of concussion incidence at the youth recreational or competitive levels. Second, there appears to be less access to comprehensive medical care in youth athletics in comparison with university or professional organizations, leading to a serious lack of consistent implementation of validated approaches to concussion management. As a result, youth more frequently return to play prematurely, increasing their vulnerability to a subsequent injury and worse outcomes. Third, we hypothesize that the concussion risk in youth sports such as football, hockey, and soccer may be high, since there is a high degree of variability in physical development, cognitive skills, and athleticism among children even at the same age, which may lead to a heightened concussion risk. To complicate matters, many youth and club teams are comprised of players within a 2-year span, and standout players are often moved up to play with older children. The heightened intensity and potential head impacts for the younger children in these situations may lead to significant injury due to less developed neck musculature. Fourth, evidence from animal models indicates that the developing brain is more vulnerable and displays a slower recovery pattern than the adult brain (Giza & Hovda, 2001). Fifth, more catastrophic outcomes (i.e., deaths) from concussion have been reported in children and adolescent cases than in adults (Halstead et al., 2010).

**Concussion incidence in high school athletes.** Not surprisingly, there has been a greater emphasis on understanding the incidence and implications of concussion on youth in recent years, as children represent the largest group of individuals playing athletics, putting them at greatest risk for injury. Powell and Barber-Foss (1999) provided one of the first comprehensive reports of concussion incidence among high school varsity athletes. They studied athletes within a 3-year period (1995–1997) and estimated approximately 62,816 concussions annually, with football accounting for 63% of these cases. A more recent study conducted by Gessel and colleagues (2007) estimated an annual 136,000 concussions among high school athletes, which comprised 9% of all athletic injuries at this level. Similar to the previous study, concussions were most prominent in football, followed by girls' soccer and basketball. More contemporary findings from an 11-year prospective study of high school athletes from 25 schools indicate that football is the biggest culprit for concussion at this level, followed by boys' lacrosse (Lincoln et al., 2011). Although lower in the total number of concussions identified, girls' soccer recorded the second highest incidence rate of concussion across the 12 sports managed. In addition, girls were nearly twice as likely to have a concussion from the same amount of athletic exposure, and the overall number of concussions across sports increased

from 1997 to 2008. The authors cited an increase in athletic trainer coverage and increased concussion awareness among medical personnel as potential contributing factors to this noteworthy finding. Overall, these findings, in combination with data from the collegiate level, have contributed to our knowledge about the relative risk of concussion within specific sports and have compelled researchers to investigate whether age and sex differences in concussion outcome exist (Broshek et al., 2005).

***Differential recovery curves in adolescents compared with adults.*** The previous evidence of heightened concussion incidence and risk factors in youth has stimulated investigations into the functional recovery of concussion in this population. It is first important to review Barth and colleagues' (1989) pioneering work in developing the Sport Laboratory Assessment Model (SLAM) so that direct comparisons between youth and adults can be made. Barth and his collaborators reported that the majority of collegiate athletes who suffered mild traumatic brain injury showed complete resolution of cognitive symptoms after 5–10 days. A history of multiple concussive or even subconcussive events led to a prolonged recovery from a symptom perspective. In contrast, Alves (1992) proposed that the physical symptoms associated with concussion diminished much more slowly, and did not completely resolve until 3–6 months postinjury. The preponderance of the evidence in the last two decades has supported Barth and colleagues' (1989) conclusion that cognitive symptoms of concussion resolve within 2 weeks in about 85% of all cases (Webbe & Barth, 2003). Alves's (1992) contention that physical symptoms may resolve more slowly in a minority of cases also has received continuing support (Sterr, Herron, Hayward, & Montaldi, 2006).

Extending the discussion to youth, children who sustain mild traumatic brain injuries (MTBI) demonstrate deficits in several cognitive domains, such as attention, processing speed, learning, and memory (Klonoff & Lamb, 1996). More recent evidence indicates that high school athletes exhibit more protracted recovery curves as well as prolonged memory deficits following concussion compared with collegiate and professional athletes (Collins, Lovell, Iverson, Ide, & Maroon, 2006; Field, Collins, Lovell, & Maroon, 2003; McClincy, Lovell, Pardini, Collins, & Spore, 2006; Meehan, d'Hemecourt, & Comstock, 2010). Moreover, Moser, Schatz, and Jordan (2005) reported that youth between 13–19 years of age with a history of two or more previous concussions performed similarly to youth who had sustained a concussion within 1 week of being administered paper and pencil testing (e.g., Trail Making Test and Repeatable Battery for the Assessment of Neuropsychological Status). These findings further support the notion that youth may be particularly vulnerable to the effects of concussion, and that repeated insults to the brain during development may lead to more persistent cognitive changes compared with adults. Unfortunately, there is a lack of comprehensive empirical data on concussion outcomes in youth, especially on preadolescent athletes.

***Concussion management issues specific to youth: Education is key.*** The literature on youth concussion indicates that a broken pipeline exists with respect to sports-related concussion management in the pediatric domain. Problems occur early on from detection of concussion symptoms to inaccurate return-to-play decisions (Bazarian, Veenema, Brayer, & Lee, 2001) and from appropriate hospital discharge instructions (Genuardi & King, 1995) to a lack of implementation of activity restrictions needed to promote symptom resolution. Misconceptions

about concussion are evident in parents and coaches, who may be only aware of obvious symptoms such as loss of consciousness (Valovich McLeod, Schwartz, & Bay, 2007) or emesis (vomiting). These findings highlight the importance of concussion education, since baseline testing is conducted less frequently at the youth level, and authority figures (e.g., parents, coaches, teachers) are relied upon for referrals for postconcussive evaluations. Adults responsible for their care also frequently provide information regarding postconcussive changes via interviews and symptom inventories; therefore, increased concussion awareness among these individuals is prudent.

Beginning in 2005 with the publication of Randolph, McCrea, and Barr's challenge that neuropsychological testing had not yet been proven to have a benefit in making return-to-play decisions following sport-related concussion, there has been ongoing controversy surrounding the empirical validation of the role of neuropsychological approaches in concussion management and return-to-play decisions, particularly when a child or adult continues to be symptomatic (Kirkwood, Yeates, & Wilson, 2006; Lovell et al., 2006; Moser et al., 2007; Randolph, McCrea, & Barr, 2005). Randolph and colleagues (2005) have suggested that the following questions about neuropsychological testing and concussion management need to be considered: (a) Are the batteries used in concussion assessment valid? (b) Is information provided by the neuropsychological assessment unique compared with other categories of testing (e.g., neurological, scanning/imaging, balance testing)? and (c) Do the neuropsychological outcomes reveal information regarding recovery of function that would otherwise not be known and that is critical for the return-to-play decision? In discussing their view of the answers to these questions, Randolph and colleagues found that the empirical validation of neuropsychological testing in the concussion management context was weak. The reaction from others in the discipline to these conclusions was not long in coming. Lovell et al. (2006) and Moser et al. (2007), among others, described outcome studies that they believed provided clear demonstration of the value-added contributions of neuropsychological testing in making return-to-play decisions. Iverson (2010) has commented that the Randolph et al. criticisms of the use of neuropsychological testing have highlighted the need for additional empirical validation of two areas: (a) the need for baseline testing and (b) the usefulness of conducting evaluations early following injury when the athlete still is symptomatic.

We propose that neuropsychological evaluations can be useful not only in assisting with accurate return-to-play decisions, but also in providing concussion education to the youth players themselves and to those involved with their care (e.g., parents, coaches, athletic trainers, pediatricians, teachers), which in turn leads to safer athletic play, earlier detection of injuries, and receipt of school accommodations during the recovery process. In addition, pediatric neuropsychologists play a pivotal role in the interpretation of cognitive and behavioral changes secondary to concussion, as they possess comprehensive knowledge of brain-behavior relations within the context of a developmental framework. This is particularly important when considering the neuropsychological profile of a youth athlete who is undergoing the normal maturation process; a simple comparison of scores between baseline and postconcussive testing does not suffice. This view is supported by McCrory, Collie, Anderson, and Davis' findings (2004), which indicate significant developmental changes in reaction time, working memory, and new learning between the

ages of 9–15. Overall, more sophisticated interpretation of neurocognitive performance is likely required in preadolescent children, especially those who may have a heightened vulnerability to postconcussive effects due to premorbid factors such as ADHD or LD (discussed shortly).

**Symptom reporting in youth athletes.** Previous studies indicate that children experience a cluster of cognitive, somatic, and emotional symptoms (Yeates et al., 1999) that may persist up to 6 months after injury in a number of concussed children (Mittenberg, Wittner, & Miller, 1997). In a more recent investigation, Moser and Schatz (2002) showed that postconcussive symptoms persisted for weeks or months in some youth athletes who had suffered multiple concussive or subconcussive blows. The current return-to-play guidelines suggest that children should not return to play if they continue to be symptomatic after a concussion, either at rest or under physical or cognitive exertion (Aubry et al., 2002; Guskiewicz et al., 2004; McCrory et al., 2005; Moser et al., 2007). Hence, appropriate symptom assessment is critical to the effective management of sports concussion in youth; however, some potential barriers exist, which may preclude the accuracy of symptom identification and resolution. Notably, there is a lack of age-appropriate scales that have been developed to assess postconcussive symptoms in preadolescent children. To further complicate matters, there are limited data available regarding the reliability and reliability change indices of the four concussion symptom scales (i.e., Graded Symptom Checklist, Post Concussion Symptom Inventory/Acute Concussion Evaluation, Rivermead Post Concussion Symptom Questionnaire, and Health Behavioral Inventory) used with children aged 12 and under (Gioia, Schneider, Vaughan, & Isquith, 2009). Furthermore, parents and children seem to differ in symptom reporting; therefore, a combination of both parent-and-child inventories may provide a fuller picture of the postconcussive symptoms experienced by youth. Indeed, children appear to report more somatic symptoms, whereas parents report increased cognitive problems (Hajek et al., 2011). The differences in these response styles may be due to children's lack of awareness of symptoms or that cognitive changes may be more easily observable to parents compared with physiological symptoms. Certainly, more empirically validated research regarding symptom reporting and postconcussion syndrome is needed in children. It remains unclear at this point whether prolonged symptom resolution in youth is solely attributable to concussion or whether premorbid cognitive, behavioral, and psychological variables may account for differential recovery curves.

**Premorbid conditions: ADHD/LD.** Consideration of premorbid conditions in concussion management is paramount because there are a number of ADHD or LD-diagnosed athletes at the youth and collegiate levels (Collins et al., 1999; Salinas, Webbe, & Devore, 2009). To our knowledge, there are no studies that have specifically explored the prevalence of ADHD or LD at various levels of athletics and how this may influence concussion incidence. This is surprising, as previous empirical data indicate that attention and learning problems are good predictors of physical injury in university students (Bergandi & Witting, 1988) and children who sustain mild traumatic brain injuries (Gerring et al., 1998). Certainly, behavioral characteristics such as inattention and impulsivity during a fast-paced sport may lead to injury in those with ADHD. In youth sports, boys with ADHD reportedly experience increased aggression, emotional reactivity, and more frequent

disqualifications across several sports (Johnson & Rosen, 2000), which may also make them more prone to injury. Future studies should directly explore the role of ADHD and LD in susceptibility to both concussion and repeat injury.

The majority of the available sports concussion literature related to baseline testing and normative data, validity and test-retest reliability of computerized measures, practice effects and reliable change indices of neuropsychological measures, as well as symptom inventories used with athletes in concussion management has excluded those with premorbid learning difficulties and/or ADHD, as including them in studies may lead to several confounding variables; however, it is not uncommon to manage athletes with concussions who have a history of ADHD or LD in clinical practice. In the absence of comprehensive empirical data for these populations, it is plausible that inaccurate interpretations of both neurocognitive performance and symptom reporting may be a frequent occurrence, leading to poor return-to-play decisions. Even when baseline data exist for an athlete with ADHD, direct comparison after a concussive effect may not reveal a significant decline, which could lead to premature return to play. In the case of youth athletes with ADHD, where postconcussive evaluations are more frequently conducted without baseline testing, it may be more difficult to delineate whether reduced neurocognitive performance is reflective of premorbid problems or concussion. Baseline testing in this population would be useful for pre- and postcomparison, as recent evidence suggests that children with ADHD differ from their peers on baseline computerized measures (e.g., Concussion Resolution Index for Children, CRI-C; Salinas, Webbe, & Devore, 2009). This finding is not surprising, as individuals with ADHD generally exhibit greater executive functioning weaknesses than their peers (including processing speed); however, these preexisting cognitive problems may lead to a protracted recovery curve (Levin et al., 2007). Collins and colleagues (1999) also reported that a history of LD mediates the outcome of concussion. It may also not be uncommon for children and adult athletes with ADHD or LD to report increased symptoms during both baseline and postconcussive evaluations. Thus, we recommend that collateral data from parents or family relatives be obtained and that these ratings along with the subjective report include both current and previous symptoms to clarify any changes that may exist.

Overall, managing concussed athletes with ADHD and/or LD adds greater complexity to return-to-play decision making and requires sophisticated interpretation and expertise, not a basic score comparison that can be conducted by a psychometrist; however, no empirically validated guidelines exist for this population, which may lead to dichotomous approaches by clinicians, ranging from overly cautious to overly lenient. In either case, this could lead to prolonged activity restrictions or premature return to play.

## **Gender and Concussion: No Simple Matter**

Over the past 30 years, coincident with the implementation of federal statute that prohibits gender-based discrimination in educational programs (“Title IX”; Title 20 U.S.C. Sections 1681–1688), females’ participation in sports has increased tremendously. This growth has occurred at all levels, but particularly in youth through college ages. For example, Cheslock (2007) reported that female participation now represents at least 42% of all athletes in high school and collegiate sports. Perhaps



the most confusing and perplexing issue in assessing the role of gender as it relates to concussion broadly, and sport-related concussion narrowly, is the seemingly contradictory data regarding incidence and risk protection. We herein review incidence data, which clearly show that females are more at-risk for concussion in sport than are males. We also will review data regarding the protective role of gender in the brain's response to trauma. Yet, making sense of the conflict is a true test.

**Concussion incidence in girls vs. boys, men vs. women.** Several recent reviews and meta-analytic studies have concluded similarly that female athletes have a higher risk of concussion than do male athletes (Covassin & Elbin, 2010; Dick 2009; Farace & Alves, 2000; Gessell et al., 2007). This outcome has been reported in high school, college, and professional sports. For example, female collegiate athletes in soccer and basketball have been found to sustain significantly more concussions than males playing the same sports (Agel, Evans, Dick, Putukian, & Marshall, 2007; Broshek et al., 2005; Dick, Putukian, Agel, Evans, & Marshall, 2007). At the professional level, Dvorak, McCrory, and Kirkendall (2007) examined injury incidence data for the highest level FIFA (soccer) competitions and found that although head injuries of all types (usually soft tissue lacerations) were equal across genders (about 12 per 1,000 player hours), the percentage of head injuries diagnosed as concussion occurred more than twice as often in women (22%) than in men (8%). In their large-scale head-to-head comparisons of sports played by both sexes (soccer, basketball, lacrosse), Hootman, Dick, and Agel (2007) found that women had higher concussion rates than men did and that concussions represented a greater percentage of all injuries.

Notable and alarming for their absence from the gender-incidence interaction literature are data from youth sports. Arguably, more prepubertal children engage in sport activity than any other cohort. Much of this activity is unregulated and even organized youth sport leagues and systems have no injury surveillance mechanisms in place (Halstead et al., 2010). Some basic data on injury are available, but these are tainted by a known underreporting confound. For example, Yang et al. (2008) reported that in an inpatient pediatric sample collected between 2000 and 2004, older age but not gender was a predictor of sport-related concussion. Directing the discussion of gender differences to children does little to clarify the situation, since few studies have reported on gendered outcomes following pediatric head injury. Indeed, when we consider prepubertal children, the many later developmental differences likely tied to hormonal changes are eliminated. No differential incidence of brain injuries in prepubertal children has been reported in the sport concussion literature (Farace & Alves, 2000). Given that the bulk of traumatic brain injury cases in pediatric samples generally derive from motor vehicle accidents and other child-independent accidents, this finding may not be surprising. The sport context is probably a better venue in which to discover any true gender differences in incidence or recovery. As noted previously, however, few studies of children have been undertaken, and even then, results are often not classified according to gender. Williamson and Goodman (2006) commented on the underreporting of concussions in youth hockey but reported only on males. Clearly, insufficient data are available in the pediatric population to draw any gender-based conclusions on incidence of concussion or on differential recovery issues. The issue deserves clarification, especially since it has been reported that girls' brains develop up to 2 years earlier than boys (Lenroot et al., 2007).

**Gender and concussion severity.** The severity of concussion can be measured in multiple ways, including levels and frequencies of acute symptoms (both self-reported and measured objectively with physical and cognitive tests) and duration of symptoms postinjury. Unlike the incidence data that are very consistent across studies, outcomes of symptom and cognitive assessments are more variable. With a mixed sample of 131 high school and collegiate athletes selected from a variety of contact sports, Broshek et al. (2005) found that female athletes performed significantly worse on simple and complex reaction times relative to preseason baseline levels and also self-reported more postconcussion symptoms. Females were nearly 1.7 times more likely than males to experience cognitive decrements posttrauma. In their evaluation of the role of concussion history on neurocognitive performance in 234 soccer athletes aged 8–24, Colvin and colleagues (2009) also compared outcomes based on gender. They reported that females complained of significantly more symptoms and scored lower than males on composite scales of the ImPACT test. In contrast, Frommer and colleagues (2011) found no consistent symptom differences based upon gender among more than 800 concussed high school students (about 25% female) representing various contact sports.

The possibility that females are more frequent reporters of symptoms generally could explain some of the data where only subjective complaints were recorded. Indeed, Covassin et al. (2006) reported that females did report more complaints at baseline than did males, and later they also reported that females and males scored similarly on baseline neurocognitive tests (Covassin, Schatz, & Swanik, 2007). When symptom reports have been augmented with quantitative measurement of neurocognitive performance, both measures showed consistent impairments in women following one concussive incident (e.g., Broshek et al., 2005; Colvin et al., 2009).

The majority of studies conclude that females report more symptoms and report symptoms for a longer duration following an incident concussion than do males. In addition, females also are observed to perform at a depressed level on neuropsychological tests for longer duration (Broshek et al., 2005; Colvin et al., 2009; Dvorak et al., 2007).

**Factors underlying gender vulnerability.** In describing the potential underlying mechanisms that control gender differences in incidence of concussion and symptomatic response to concussive blows, we can differentiate positive versus negative risk factors. For example, weaker musculoskeletal support for the head, which exacerbates the acceleration of the head and brain induced by an externally applied force, appears to be the critical factor which might control higher rates of concussion in females, increased cerebral perfusion in females, and increased rates of glucose metabolism in females (Dvorak et al., 2007; Tierney et al., 2005). Indeed, Tierney and colleagues directly measured the response of the head-neck segment to external blows and found significantly greater stability in men versus women. The presumption is that such differences would also apply to adolescents and possibly also prepubertal children. Even when a cue preceded the blow, women's preparatory response was insufficient to alter the resultant acceleration of their heads, whereas men did successfully reduce the effect (Tierney et al., 2005). Tierney et al. speculated that the "reason for the greater head-neck segment angular acceleration in females may be related to their lower levels of strength, neck girth, and head mass, resulting in less head-neck segment stiffness compared with males" (p. 277).

If physical capacities delimit a positive risk for concussion for females, physiological and metabolic factors argue theoretically for negative risk. Studies with mice, rabbits, and cats have shown rather conclusively that the sex steroid hormone progesterone is neuroprotective following traumatic brain injury (Bramlett & Dietrich, 2001; Stein, 2008). The extent of progesterone's positive impact following TBI is impressive, including reduction of both vasogenic and cytotoxic edema, reduction of lipid peroxidation and oxidative stress through indirect inhibition of free radical activity, inhibition of inflammatory processes, and even prevention of apoptotic processes (Stein, 2008). Regrettably, the animal work has not yet translated into demonstrated effects in clinical studies with humans. In 2003, Coimbra, Hoyt, Potenza, Fortlage, and Hollingsworth-Fridlund reported that compared with animal studies, no protective effects of gender on any outcome measure were seen in a sample of 914 consecutive female patients with all levels of TBI. Exclusion on older patients had no impact on results. The authors concluded that *no evidence* of post TBI protection was afforded by gender in clinical patients. Indeed, such outcomes appear the norm in sport-related concussion studies, where female athletes report more symptoms and more severe symptoms in acute and chronic assessments. One glimmer of light was the preliminary report by Wright et al. (2007) of a phase II clinical trial of progesterone. This study evaluated 100 male and female patients who had suffered moderate to severe brain injury following blunt force trauma to the head. In this randomized control group designed study, some patients received placebo along with standard emergency and follow-up treatment. The progesterone group received 3 days of postinjury continuous intravenous drip. After 30 days, the severe patients receiving progesterone had significantly lower mortality than the placebo group. For the patients with moderate trauma, those receiving progesterone had significantly better functional outcomes than the placebo group as measured by the Disability Rating Scale (DRS; Rappaport, Hall, Hopkins, Belleza, & Cope, 1982). These findings stand alone as the only human demonstration of progesterone's efficacy in treating TBI. It remains unknown whether these promising findings might hold true in the larger phase III trial begun in 2010 or apply to cases of concussion.

It is important to note the difference in administration of significant loading doses of progesterone to victims of brain trauma versus merely differentiating male versus female gender in attempting to explain concussion risk and concussion protection. Progesterone levels are not much different in males and females except during the females' luteal phase when concentrations rise considerably (Yoshimi & Lipsett, 1968). Given this fluctuation, through the menstrual cycle, any natural neuroprotection afforded women would be time limited. It is probably fair to conclude that the variance in negative concussion risk accounted for by these periodic highs in progesterone concentration may be modest in comparison with the positive physical risk factors of head-neck stability. More research is warranted.

## **The Role of Culture and Language in Concussion Management**

Just as the sports arena has been a laboratory for studying concussion, the inherent cultural dynamics of "the game" provide neuropsychologists a vast opportunity to investigate cognition from a cross-cultural perspective. Sports such as soccer have

been played around the world for centuries, but even sports like golf and martial arts have emerged in nonindustrialized nations due to the nature of globalization. Historically, sports have been a common denominator among individuals from all walks of life, regardless of race, gender, educational background, or country of origin. Indeed, sports participation has even led to cultural paradigm shifts in the status quo with athletes such as Jesse Owens in the 1936 Olympics who made the headlines, and detracted from Nazi propaganda. Other African American legends in subsequent decades such as Jackie Robinson and Mohammad Ali changed the face of their respective sports. The National Hockey League (NHL), an initially Canadian driven sport, now has far more teams in the United States than in Canada, and has gained overwhelming popularity in European countries. Major League Baseball (MLB) has also seen a dramatic increase in Hispanic players in previous decades, perhaps sparked by the 3,000 hits made from Roberto Clemente. More recently, former National Basketball Association (NBA) player, Yao Ming, became a pivotal force in internationalizing basketball in the East, particularly China. Taken together, neuropsychologists are sure to face a mix of culturally diverse athletes during the evaluation and management of sports-related concussion.

Despite this picture, empirical data regarding the cultural equivalence of computerized cognitive measures such as ImPACT (Maroon et al., 2000) and symptoms inventories that are used for baseline and postconcussive evaluations are sparse. There is limited evidence to support whether test-retest outcomes and postconcussive cognitive effects reported in the previous literature generalizes to all athletes regardless of ethnic minority, educational, linguistic, and country of origin statuses. These issues reinforce the need for an individualized approach to test interpretation and concussion management and highlight the unique and specialized knowledge that neuropsychologists can contribute in forming return-to-play decisions for athletes in these situations. The issue of cultural competence in sports concussion management is important given the diversity of athletes at all levels, and the growing body of scientific literature that indicates variable neuropsychological performance when cultural and educational variables, including bilingualism, are considered (Manly, Jacobs, Touradji, Small, & Stern, 2002; Manly et al., 1998; Puente & Puente, 2009). Although computerized batteries such as ImPACT have been translated into several languages, linguistic and cultural variables have often been overlooked in the majority of investigations emphasizing sports-related concussion. Surprisingly, we were only able to find data from one investigation that emphasized the role of linguistic variables on neuropsychological performance on both traditional measures and computerized tests. Echemendia and Comper (2008) reported significant testing differences between athletes in the NHL based on cultural and linguistic background; these differences emerged when players were evaluated in both English and their native languages. Despite the lack of comprehensive data in this area, this issue is not trivial, given both the large percentage of international athletes at the professional level and bilingual youth. Indeed, the issue of whether cultural variables can lead to different baseline performance on computerized testing and specific domains such as reaction time remains an open question and requires direct research investigation. In addition, we propose that tasks that are theoretically “culture free” such as reaction time require additional consideration, as more recent evidence indicates that culture may mitigate performance on timed tasks (Agranovich, Panter, Puente, & Touradji, 2011).

**Cross-cultural test findings.** Recently, Shuttleworth-Edwards, Whitefield-Alexander, Radloff, Taylor, and Lovell (2009) conducted a study that investigated the neuropsychological profiles of the ImPACT on age-matched South African rugby and U.S. football players from 11 to 21 years of age. No significant differences across test domains were reported; however, South African athletes reported more symptoms on the initial symptom questionnaire. The authors concluded that the ImPACT test was equivalent for South African athletes whose first language was English and who came from economically advantaged backgrounds. It is unclear whether their findings will generalize to athletes with a limited educational background. Interestingly, this study highlights how cultural background may also influence symptom manifestation and whether culture may mitigate one's physical response to injury. This also brings into question whether cultural dynamics may influence the type of feedback provided to the athlete and in various collectivistic cultures, how family or community personnel may be involved in the process. This may be particularly important as it relates to school reentry in other countries when managing youth athletes.

Clearly, the need for linguistically appropriate tests was met with the development of ImPACT in several languages. There is an ongoing assumption, however, that the normative data cited by the authors of ImPACT and other computerized measures represents athletes at all levels, regardless of their ethnic status or educational background. Since there is a lack of empirical data to support the contrary, ongoing utilization of these instruments persists nationally. Yet, special consideration of these variables may be warranted, as previous research has shown that cultural background, particularly quality of education and socioeconomic status, has an impact on neurocognitive performance (Manly et al., 1998). More recently, there have been two studies that have investigated neurocognitive performance with Hawaiians and African Americans (detailed below).

Tsushima and Oshiro (2008) explored the normative data for Hawaiian adolescent players ( $N = 728$ ), ranging from 13 to 18 years of age who came from four Oahu public high schools. Although this investigation had several limitations, including a lack of direct statistical comparisons between Hawaiian and U.S. Mainland norms, the means and standard deviations reported were remarkably similar to those reported by McClincy and colleagues (2006). The authors also reported a trend toward mildly reduced performance among Hawaiian adolescents, leading to a lower cut off for the impaired classification in this group versus the traditional U.S. normative set. This difference is not trivial, as utilization of U.S. Mainland norms in this population may result in a high number of false positive errors, leading to prolonged return-to-play decisions in this group. Notably, Tsushima and Oshiro reported that their Hawaiian sample might have had a lower quality of education, which may account for the subtle differences noted compared with the U.S. Mainland data. In addition, a large percentage (27.6%) of the sample reported a history of at least one previous concussion, which may have contributed to their lower performance. Nevertheless, these preliminary findings highlight the need for additional research that investigates the influence of factors such as geographic or ethnic minority status on neurocognitive performance on computerized measures.

Kontos, Elbin, Covassin, and Larson (2010) recently explored potential differences in pre and postconcussion performance on the ImPACT test between African American and White high-school and collegiate athletes, most of whom were male

football players. No significant differences between these groups were found at baseline, indicating that the ImPACT test is reasonably equivalent and has good construct validity for athletes from these specific racial/ethnic backgrounds. More importantly, however, Kontos and colleagues found that African Americans might be particularly vulnerable to postconcussive effects compared with their White counterparts, although this data should be considered preliminary in nature. Although the majority of their analyses were not statistically significant, African Americans did not demonstrate a trend toward a practice effect in motor processing speed at 7 days postconcussion, as the White athletes did. The results of a Chi Square analysis and Odds Ratio also indicated that the African American athletes were 2.4 times more likely to experience one clinically significant cognitive decline than were the White athletes. Many underlying reasons for these differences were identified, such as potential differences in multiple unrecognized or unreported concussions, subtle differences in the quality of education, and attitudes during the one-to-one test-taking condition during the postconcussive period due to examiner-examinee racial differences (e.g., African American athletes were usually evaluated by White sports medicine professionals). Clearly, more research is needed to confirm these findings and delineate these differences, and future studies should continue to directly evaluate how cultural and linguistic background may influence cognitive performance within the sports concussion context.

## Nature of Sport

Clearly, different sports have the potential for different risks of concussion. For example, any sport that combines speed of movement with the potential for physical contact will have a greater concussion risk than static sports. We could compare lacrosse with golf in this context. Use of equipment, such as sticks and balls that can impact the head, correlates with such risk. Sports where acceleration exists in multiple planes may carry the highest risk of concussion. For example, in rodeo bull riding, the rider experiences simultaneous, intense accelerations in vertical, lateral, and horizontal planes. Review of such relationships has been accomplished elsewhere (e.g., Broshek, Brazil, Freeman, & Barth, 2004; Ruchinskas, Francis, & Barth, 1997).

Unique among sports, since it promotes instrumental use of the head for redirecting the flight of the ball, soccer participation comes with the dual risk of (a) cumulative injury due to repetitive subconcussive blows to the head and (b) repeated instances where head injury may occur due to contact with external objects and forces. The latter risk is similar to that found in football and hockey. The former is unique, and the impact of the heading factor on later neurocognitive impairment remains unknown and somewhat controversial. As Webbe and Salinas (2010) have described, there likely are idiopathic factors underlying neurocognitive risk to subconcussive blows, and thus far these factors lack phenotypic identification. The challenge to the neuropsychologist is to be prepared to recognize the earliest manifestations of such individual responses and to intervene accordingly (Webbe & Ochs, 2003).

Of interest to the current discussion is the interaction of sport type with populations that confer hidden or unique risk. For example, when considering the interaction of sport with age for the risk of concussion, size and strength differentials

become critical. Most youth sports are organized according to age classifications to group children according to developmental characteristics such as size, intellect, strength, and acquired skill. Naturally, individual differences may be considerable and the intent for homogeneity often falls short. In sports such as football, hockey, and soccer, where 2-year age groups are the norm, it is common for vast differences to exist in size, weight, and strength of children. In such instances, risk of injury, including concussions, increases.

Cheerleading is an example of an activity that has evolved over time into a sport, but that stayed under the radar of many observers since its classification as a sport was somewhat controversial. The continued development of athleticism, complexity, and riskiness of routines, coupled with the move toward sanctioned competitions, suggests that modern cheerleading certainly qualifies as a sport. Coincident with the rise of this sport has been attention toward injury risk, including risk of concussion. Schulz et al. (2004) studied injuries among 1,675 competitive cheerleaders from North Carolina high schools. Concussions accounted for 6.3% of all injuries observed during this period. In a study limited specifically to cheerleading injuries caused by falls, Shields and Smith (2009) reported that 6% of all injuries were concussions. Although this percentage does not place cheerleading among the sports with the highest rates of concussive injuries, the figure is certainly alarming and warrants close monitoring and management, just as with other high-risk sports.

Extreme sports represent activities that generally exceed traditional sports in injury risk. As defined by Willig (2008), "extreme sport may be defined as recreational physical activity, which carries a risk of serious physical injury or even death" (p. 691). Although there is no accepted catalog or definition of such activities, these sports have often been alternative in contrast to historical mainstream sports. Extreme sport participants also debate over authenticity versus inauthentic participation and motivation (Donnelly, 2006). This debate is not trivial, since "core" participants may be more likely to adopt riskier behaviors regarding injury and may engage in the sport in relative isolation from possible emergency assistance. Indeed, as extreme sports take on some commercial values, participants may leave them behind for even more risky adventures. Some of the most commonly mentioned extreme sports include snowboarding; skateboarding; street luge; bicycle moto-cross (BMX); mountain biking; sky-diving; building, antenna, span, earth (BASE) jumping; big wave surfing; extreme skiing; bull riding; bungee jumping; and rock climbing. In BMX riding, snowboarding, and skateboarding within half-pipe venues, the accelerations during tricks may be less intense, but combinations of multiple accelerations at the time of falls may produce very destructive forces that act on the head and brain. The predominant appeal of extreme sports is to young participants, and such events often include an outlaw or at least counter-culture aura. These two factors probably contributed historically to a lack of oversight or sanctioning, although organization and regulation does tend to follow popularity. Thus, many of these activities now have structured competitions and organizations that maintain at least a loose regulation. Because extreme sports have existed at the fringe of organized regulation or sanctioning, historical injury data are sparse. For example, the National Electronic Injury Surveillance System (NEISS), maintained by the Consumer Product Safety Commission, combines snow skiing and

snowboarding (both downhill, half-pipe, and other variants) into one category, making it difficult to ascertain specific injury rates. As snowboarding has entered a more mainstream phase, injury data are more forthcoming, and the data are not surprising. For example, Hasler and colleagues (2010) have noted that failure to wear helmets is a significant risk factor for head injuries in the sport. Unfortunately, the historic aura of snowboarding has reinforced a “freedom from helmets” ethic that public education is only gradually eroding. Indeed, as we commented earlier when discussing pediatric issues that education remains the key for reducing head injury risk in all sports. Public unawareness of the various extreme sports will serve only to bury a mounting injury problem.

## Summary and Conclusions

The study of sports-related concussion historically focused on American football players. Yet, as awareness developed of the prevalence of concussions throughout contact sports, a more international focus ensued, culminating with conferences that produced consensus documents that emphasized neuropsychological evaluation as a key component of the concussion management process. As a result, baseline testing and postinjury assessments have become commonplace at the collegiate and professional levels across the majority of sports in the United States, and a number of high school management programs have been developed around the country. Since neuropsychologists have specific expertise with test construction and psychometrics, as well as the understanding of brain-behavior relationships, they have made positive contributions to this area of scientific investigation by showing that (a) neurocognitive measures are valid and reliable indicators of concussion; (b) neuropsychological evaluations can be used to understand the nature of a concussion and track the cognitive and behavioral sequelae of an individual athlete; (c) neuropsychological evaluations have an added value in the management process, since some asymptomatic athletes continue to show cognitive changes; and (d) objective data can be useful in predicting outcome and mitigating concussion risk so that athletes can safely return to play. In the last two decades, many questions have been answered regarding concussion incidence, injury-related variables, and severity across various athlete populations. Theoretical hypotheses regarding the underlying mechanism of concussion have also been proposed and largely supported by animal models.

More recently, there has been a push for understanding specific epidemiological risk factors that may increase one’s vulnerability to concussion and identifying underlying factors that may help explain the variability in outcome often seen in clinical practice. We propose that increased understanding of these factors can lead to more individually tailored assessment and more effective treatment of athletes who have suffered concussion. Hence, herein we reviewed how intrinsic conditions such as age, gender, and preexisting ADHD/LD and extrinsic factors such as sport played can potentially influence concussion risk, injury severity, and recovery. We also highlighted how one’s cultural and linguistic background may influence neuropsychological assessment within the sports context. In summary, the following main points summarize the most contemporary findings available in these athlete populations:



- Youth appear to sustain more concussions than adults playing the same sport and the outcomes are generally worse, with more persistent cognitive changes and symptoms reported in the literature. Tracking and management of sport-related concussions in pediatric populations remains in its infancy.
- Females appear to have a higher incidence of concussion when compared with males with the same amount of athletic exposure (more notable in sports such as soccer and basketball), and they report more severe symptoms for a prolonged period of time. The interaction of anatomical features with applied biomechanical forces appears to support a gender difference as opposed to simply more reporting of symptoms by females.
- Preexisting ADHD or LD appears to be a confounding factor in the interpretation of both baseline and postinjury assessments, and LD appears to worsen concussion outcome in collegiate athletes.
- More recently, emergent findings suggest that symptom manifestation as well as baseline and postinjury data may be influenced by athletes' cultural and linguistic background, including on tasks that are not verbally mediated. Interpretation of neuropsychological data in return-to-play decision making should consider factoring in such cultural and linguistic variables.
- Traditional sports that involve speed and contact, such as football, hockey, and soccer, remain high-risk activities for concussion. Because of the inherent risk of concussion even when adhering to the rules, and because of the large number of participants worldwide, focus on concussion education, identification, and management remains a critical priority.
- Newer sports and recreational activities such as skateboarding, extreme skiing, snowboarding, BMX, and BASE jumping, not only place athletes at an extremely high risk for concussion but also may occur in venues that are unmonitored, thereby increasing the chances of unfortunate outcomes following accidents. Moreover, these sports often attract children and adolescents, which creates a significant interaction of risky sport, poor monitoring for concussion, and a population already more vulnerable to concussion.

Future investigations in the area of sports-related concussion are likely to continue to focus beyond the nature and course of concussion to more individually based variables such as behavioral genetics and even more sophisticated diagnostic techniques such as functional neuroimaging. However, continued emphasis on diverse athlete populations such as those discussed herein will be needed within the context of traditional and computerized cognitive batteries to ensure that these groups are properly managed.

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