A review of modifying factors affecting usage of diagnostic rating scales in concussion management

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Abstract

Sport-related concussion has gained increasing recognition as a result of recent legislation, public health initiatives and media coverage. Moreover, there have been substantial paradigm shifts in the management of concussion. This article will discuss the variables that affect the use of diagnostic rating scales such as ImPACT and SCAT in the current management of concussed individuals. Specifically, patient-specific modifying factors affecting test interpretation, including age, gender, fitness level, psychiatric conditions, learning disorders and other components of medical history will be addressed, as well as methodological concerns with baseline testing.

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1. Introduction

Growing recognition of sports-related concussion through recent legislation, public health initiatives and media coverage has resulted in a national increase in the number of concussions evaluated in the past decade. Reports have suggested that the combination of these factors has led to a 5-fold increase in the number of youth-athletes presenting for concussion at medical centers [1]. Importantly, as many as 3.8 million concussions occur in the U.S. each year during competitive sports and recreational activities [2]. Moreover, these values are likely underestimates, according to evidence that suggests that as many as 50% of concussions may go unreported [2]. Given the mounting number of concussive injuries receiving medical attention, the importance of effective diagnostic and management strategies cannot be underestimated.

Consequently, the medical community faces the challenge of developing guidelines, care systems and tools to evaluate athletes efficiently, follow outcomes, and understand the potential long-term effects of concussion and repetitive head injury. These issues have been addressed in numerous ways by respective institutions and disciplines, resulting in significant variation in the care and management of athletes with concussion. Moreover, there have been substantial paradigm shifts in the management of concussion, which is moving toward an individualized, patient-centered method for assessment and treatment [1, 3]. Physicians attending to concussed patients should be familiar with the myriad of changes to guidelines and other current research. Furthermore, consistent and effective administration of tests and supervision of return-to-play may have significant benefits, such as prevention of repeat injury and reduction of institutional resource utilization [1]. This article will elucidate the considerations that should be taken into account when managing concussed individuals and utilizing the currently available evaluation tools, including the testing modality, patient history and other methodological concerns.

2. Concussion management

Concussion is defined by the 2012 Zurich Consensus Statement on Concussion in Sport as “a complex pathophysiological process affecting the brain, induced by biomechanical forces” [4]. Concussion results in rapid onset of short-lived impairment of neurologic function that typically resolves within 7–10 days following injury, though certain factors, such as age, gender and prior history of concussion, may prolong recovery. The foundation of concussion management involves physical and cognitive rest until acute symptoms resolve [4, 5]. Though concussive symptoms typically resolve within one week of injury, return-to-play should not be considered unless the athlete is completely asymptomatic [6]. Moreover, return-to-play should not be endorsed unless the athlete has returned to baseline or normative values on neurocognitive and balance testing [7]. Once asymptomatic, a graded program of activity is implemented before medical clearance and return-to-play is granted [4]. Currently, there is no evidence for an effective intervention to increase the rate of recovery of concussion [6]. Furthermore, no randomized, controlled clinical trials have been conducted to examine the effects of rest versus exercise, or other specific intervention [5].

3. Test interpretation

Currently, there is overwhelming evidence that assessment and management of sport-related concussion should involve a multifaceted approach. Indeed, the consequences of concussion, including symptom severity, changes in neuropsychological function and postural instability often appear to be unrelated and are affected to different degrees after injury [8]. Therefore, the evaluation should include a clinical exam, self-reported symptom checklist, postural assessment and neurocognitive testing [9–11]. In particular, evaluation of cognitive functioning should include intellectual functioning, academic skills, attention and concentration, processing speed and learning, memory, psychomotor function and emotional functioning [12]. To facilitate objective and comprehensive evaluation of concussed individuals, the most commonly used assessment tools include the PCSS, SAC, SCAT2 and ImPACT [5]. However, the sensitivity, specificity, validity and reliability of these standardized tests remain largely undefined, particularly among different age groups, cultural groups and settings. Moreover, no single test has demonstrated sufficient sensitivity to warrant standalone use, though the combination of multiple assessment tools may increase sensitivity and specificity of diagnosis [2, 13]. Therefore, the sports-medicine practitioner must not rely on any one tool in managing concussion, and must be aware of the advantages and drawbacks of whichever method is incorporated into the evaluation and management plan [11]. These considerations are of critical importance for reducing the risk of additional injury [13]. Additionally, test interpreters must recognize that the reliable change difference scores serve as a supplement, rather than a substitute to clinical expertise in this area [14].

4. Patient-specific modifying factors affecting test interpretation

Due to the complexity of brain function, concussion is a highly individualized injury, with significant variability in the type and severity of concussion presentations in the acute setting [6, 14, 15]. The specific symptoms reported by patients are modulated to some degree by the particular regions of the brain affected, as well as the social, educational, occupational and medical histories of the individual [12, 16]. In fact, numerous factors have been identified that modify the risk of sustaining a concussion or alter the progression of recovery. Such factors include history of prior concussion, impact location and magnitude, severity or duration of symptoms after concussion, age, gender, genetic predisposition, history of learning disorder, Attention Deficit Disorder (ADD), migraines, mood disorder, fitness, and engaging in sports positions that could potentially involve repeated head trauma (boxer, lineman, hockey, etc.) [8, 11, 17–19].

4.1. Age

Age has been proposed as the most important factor in recovery time [8]. Evidence indicates that children appear to be more susceptible to concussion from the same amount of force than adults and that they require a longer recovery period [6]. Prolonged recovery on verbal memory, visual memory and reaction time has been observed among younger concussed athletes compared to older concussed athletes [7]. Specifically, athletes aged 13–16 take longer to return to their neurocognitive and symptom baseline than athletes aged 18–22 years [20]. Similarly, Valovich McLeod et al. found that 9th graders scored significantly lower on SCAT2 total score than 11th and 12th graders [21]. The development of Child SCAT3 and the Pediatric ImPACT test reflects the growing recognition of this elevated risk among young athletes and the specific needs of this population.

4.2. Gender

Studies have suggested that the incidence of concussion is higher in male athletes compared to female athletes [5]. This may be attributed to greater male participation in sports in which there is
inherently a higher risk of concussion, such as football or ice hockey [5]. In addition to the higher incidence of sports-related concussions, male athletes were also found to score significantly lower than their female counterparts on a number of baseline measures, including balance, immediate memory, concentration scores and the total SCAT2 score [11,21,22]. Therefore, gender may need to be considered in the interpretation of post-concussion test results and in the use of normative data as comparison.

Interestingly, despite the greater incidence of concussions in male athletes, several studies have suggested that female athletes experience worse outcomes than males after concussive injury [5,8]. In particular, female concussed athletes were found to be more cognitively impaired and have more concussion symptoms than male concussed athletes [35]. However, this discrepancy may be the result of greater willingness among females to report symptoms than males [8]. Indeed, women frequently report more somatic symptoms than men, such as headache, fatigue and dizziness [5,8,35]. In addition, several factors specific to women have been investigated [24]. Specifically, in a sample of 36 healthy college-aged females, no effect of menstrual cycle phase on concussion symptom scores was found [11]. Additionally, fewer symptoms were reported by oral contraceptive users than eumenorrheic females, both in terms of total symptom severity score and number of symptoms endorsed [11]. These considerations highlight the importance of understanding the individual factors that may affect concussion assessment and test interpretation.

4.3. Test setting

The sport setting contributes certain challenges to test administration and interpretation. For example, when the symptom scale is being completed after exercise, evaluation must be completed while the athlete is in the resting state, at least 10 min post-exercise, to mitigate the effects of fatigue on symptom reporting [4]. In addition, test administrators must be aware that athletes are often less willing to report symptoms when there is external pressure or a strong desire to return-to-play [8]. Therefore, the test should be administered in an area removed from the sideline and away from coaches, teammates and parents, if possible.

In addition, Mihalik et al. observed that subjects with low sleep quantity the night before baseline reported a greater number of symptoms and higher total symptom severity score [25]. Meanwhile, no clinically significant effects for sleep quality were observed. The authors conclude that sleep deprived athletes reporting for baseline testing should be rescheduled for testing after a normal night’s sleep [25]. Additionally, Giza et al. observed that athlete-specific characteristics, including body mass index of greater than 27 kg/m² and training time less than 3 h weekly, likely increases the risk of concussion [24].

Fitness level also appears to influence athlete performance on concussion assessments. Mrazik et al. evaluated the effect of physical fitness on self-report of baseline concussion symptoms in collegiate athletes and students and found that fitness accounted for a significant amount of variance in SCAT2 symptoms at baseline [17]. Indeed, fitter individuals reported fewer symptoms at three time intervals. In addition, exercise seemed to induce concussion symptom reporting [17]. Similarly, in a study in which 60 healthy participants engaged in 15 min bursts exercise, symptoms increased significantly after intense exercise and somewhat increased after moderate intensity exercise [11]. These results highlight the importance of timing and setting when administering concussion assessments and confirm the need for the athlete to return to resting state prior to testing.

4.5. Sport specific factors

The risk of concussive injury may also vary by sport setting. For example, the risk of concussion appears to be greatest in American football and Australian rugby, while the risk is lowest in baseball, softball, volleyball and gymnastics [24]. Similarly, an athlete’s particular position may affect their risk of concussion. In American football, it has been suggested that linebackers, offensive linemen and defensive backs are at greater risk of concussion than receivers [24]. Quarterbacks appear to be more vulnerable to recurrent concussion and are more likely to have a prolonged period before return-to-play [24]. In soccer, it has been reported that goalkeepers sustain significantly more concussions than forwards [36]. Thus, the sport and position may need to be considered in the interpretation of baseline and post-concussion test results.

4.6. Psychiatric conditions

Psychiatric conditions may play an important role in the concussion management process. In a study by Bailey et al., the authors obtained several significant correlations of moderate to large effect between baseline neurocognitive performance and anxiety, depression, substance abuse and suicidal ideation [26]. A substantial portion of the athlete participants endorsed symptoms of psychological distress, and the results suggest that psychological distress has a moderate to large effect on baseline concussion testing, diminishing performance among individuals experiencing such distress. Indeed, participants with suicidal ideation showed significantly slower simple reaction time and complex reaction time on the CRI, with a similar trend of processing speed [26]. These results underscore the importance of screening for psychological distress during baseline and post-injury concussion evaluations.

4.7. Learning disability

Similarly, recent investigations are now examining existing diagnosis learning disabilities as risk factors for concussion [5]. Individuals with learning disorders may exhibit common symptoms of concussion prior to injury, such as difficulty in learning, concentration, attention and memory. Therefore, such traits may be exacerbated following concussion (Borich et al. [5]). Up to 16% of children in the U.S. between the ages of 3 and 17 have either Attention Deficit Spectrum Disorder or a learning disability [27]. Zuckerman et al. observed that participants with attention deficit hyperactivity disorder (ADHD) administered the ImPACT assessment battery had significantly lower verbal memory, visual memory, visual motor processing speed scores, along with significantly higher reaction time, impulse control and symptom scores compared without learning disorders or ADHD [27]. Participants with learning disorders had similar results to those with ADHD, but did not differ in their impulse control score compared to those without learning disorders or ADHD. These authors provide preliminary normative neurocognitive data for these special populations [27]. Similarly, Maerlender et al. found that increased symptoms of current anxiety were associated with poorer scores on the processing speed composite of the ImPACT battery [28].

4.8. Medical history

Evidently, the medical history of the patient is an essential factor that must be considered in the management of concussion. Concussion history is of critical importance. Indeed, it has been observed that those who have sustained multiple concussions are...
at increased risk for long term cognitive impairment and have a greater probability of suffering a subsequent concussion [5]. In a study conducted by Meehan et al., 30.5% of patients diagnosed with sports-related concussion reported previously undiagnosed concussions [29]. These patients were more likely to have lost consciousness with their current injury and had a higher mean PCSS score than patients without previously undiagnosed concussions [29]. In addition, history of migraines may be relevant in evaluating concussed individuals. Indeed, studies have shown that concussed individuals with post-traumatic migraine require prolonged recovery compared to those who do not experience headaches after the injury [30]. However, the causal relationship between migraines and concussions has not yet been established.

5. Baseline testing

The principal paradigm for management of sports-related concussion includes acquisition of pre-injury or baseline performance level for comparison in the event of later concussive injury [12]. Given that individuals exhibit a range of cognitive performance in attention, memory, concentration, information processing and reaction time, baseline neurocognitive testing is purported to provide the most accurate representation of an athlete’s pre-injury cognitive status [9]. Knowledge of an individual’s baseline performance allows detection of relative deficits, and reduces potential false positive errors and the risk of misdiagnosis [29,31,32]. In fact, it has been reported that baseline neurocognitive testing has resulted in an increased detection of post-concussion neurocognitive impairments [9].

However, concerns regarding the psychometric and methodological properties of current test approaches have called into question the effectiveness of the baseline model [2,12]. While pre-injury baselines help to reduce the error due to individual differences, they also introduce additional complexity in the interpretation of test data because of measurement error associated with a second test administration [18]. Moreover, it has been suggested that administering baseline neurocognitive testing to athletes in a group setting in their school, rather than individually in a private neurological clinic, may introduce error which weakens test performance [33]. Preseason testing also functions under the assumption that the athlete has made an honest effort [2]. Moreover, baseline evaluations on one measure should not be used as the basis for post-concussion assessment using another measure. Indeed, Schatz and Putz (2006) revealed modest correlations between ImPACT and CogSport (0.65) and between ImPACT and HeadMinder (0.41), and no correlation between CogSport and HeadMinder [34].

Valovich McLeod et al. examined baseline performance on SCAT2 and observed variability among healthy adolescents, indicating that the assumption of a perfect baseline score of 100 is not appropriate in the adolescent population [21]. Similarly, Jin-gui et al. found the average SCAT2 score for high school athletes to be 89 of a possible 100, with a standard deviation of 6 units [22]. In general, non-concussed high school athletes score near the total possible in most domains of SCAT2, with the exception of concentration testing and balance testing [22].

6. Conclusions

The vast and increasing number of individuals presenting with concussion has created a growing need for effective and efficient diagnostic and management strategies. There are many clinical and non-clinical factors that must be considered in the evaluation of concussion. Greater understanding and integration of these considerations into medical practice will likely improve patient care and prevent premature return-to-play, and repeat injuries that may occur as a consequence.

References


