

# A Literature Review Examining the Potential Role of the ImPACT to Evaluate Probable Concussions in Athletes

Grant Chiasson and T. Scott Smith

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) is proposed to represent the most widely-used tool for the detection and management of concussions. With the growing rate of concussions in the high school population, there is a need for the validation of concussion detection and management to ensure the best possible outcomes for athletes' health. There has been extensive research done in regards to the ImPACT in the last decade. The ImPACT's validity is regularly researched; however, future methods should aim to focus on the baseline testing in the initial phase of concussion management. Also, the importance of baseline testing should be incorporated into the education on concussions for the high school population, as well as youth sporting groups. Athletes need to know the significance of head injuries and how improper treatment could do more harm than the concussion itself. This article offers a literature review concerning this timely topic, and additionally presents recommendations for future research endeavors.

*Keywords:* Concussion, ImPACT, Baseline Testing

Sports represent a vital component to society. Perks (2007) stated that sports positively impact social capital, which is the features of social organization such as networks, norms, and social trust that facilitate coordination for mutual benefit. There are also health and wellness components pertaining to sports in society. Beyond these remunerations are social and cognitive benefits as children learn to interact with others and develop their cognitive skills that contribute to academic achievement (Bailey, 2006).

Unfortunately, and with acceptance of reality, as a result of the active participation in sports, there is a greater chance of injury. In a study by Monroe, Thrash, Sorrentino, & King (2011), it was found that the most common type of injuries in sports was head injuries, followed by lacerations, and then fractures. Within the realm of high school sports, concussion represents a growing concern for all types of athletes. Concussion management and testing has become and continues to be a necessity in the high school setting, with assessment and early detection representing a growing area of interest.

The earliest of neurocognitive testing started in the days of Sir Franz Joseph Hall and the field of phrenology, which focused on the functional localization of the

brain (Simpson, 2005). Once intelligence testing became popular, extending from the 1890's to early 1950's, cognitive tests were developed to further the goal of measuring intelligence (Snowman & McCown, 2013). Now, in the modern age of neuropsychological testing, the platform has transitioned to computerized testing. Computerized testing has aided both the clinicians and researchers with a broad horizon to explore (Epstein & Klinkenburg, 2001).

While there are many different neurocognitive tests for clinical and research purposes, there are three that are primarily utilized for concussion management utilizing a computerized format; the CogState, CNS Vital Signs, and the ImPACT. It may be suggested that the ImPACT version 2.0 represents the most commonly used neurocognitive test in the management and diagnosis of sport-related concussions. This version contains six neuropsychological tests designed to measure different aspects of cognitive functioning. Within these six tests there are four generated composite scores, including verbal memory, visual memory, visuomotor speed, and reaction time. Numerous studies have examined the validity and reliability of the ImPACT, which will be reviewed in the scope of the present paper. A review of the literature suggests that

there may be an underreporting of symptoms on the baseline test to avoid losing playing time after a possible concussion. This article addresses the potential role of the ImPACT as a tool to not only assess, but also manage head injuries, particularly within the context of sports management.

## Literature Review

When considering the format of a literature review, there are two distinct types. The first represents a thematic literature review. The researcher identifies a theme, and then proceeds to cite the literature based on the theme. The author discusses the main ideas from the study and subsequently does not actually take voluminous specific details from any of the studies. Contrary to thematic literature review, the next model is the study-by-study review of the literature. This study provides a broad theme with specific details about each study throughout the review. The method chosen for the present review of the literature is a study-by-study review.

**Schatz, Pardini, Lovell, Collins, & Podell (2006).** Phillip Schatz and colleagues led the movement to better understand the foundation of neurocognitive testing for concussion management and diagnosis. Specifically, Schatz utilized the ImPACT. It is understood that sustaining a concussion enhances the chance of sustaining another concussion, especially if an athlete does not recover properly from the initial concussion. Neurocognitive testing has been identified as one of the essential cornerstones of concussion management offered in the last two decades. With the substantial increase in concussions in the sports population, researchers have aimed to identify the best form of assessment and its characteristics. It was suggested that the movement of identifying concussions based on baseline preseason neurocognitive testing and comparing values to of the tests post-concussion should be re-invented. It was also suggested that it is important to note that neurocognitive testing alone is more accurate when the symptoms are self-reported in concurrence. The ImPACT utilizes both of these features and has been tested regularly to yield valid and reliable results.

**Fazio, Lovell, Pardini, & Collins (2007).** Fazio, Lovell, Pardini, & Collins (2007) began the identification of the relationship between post-concussion symptoms and their relationship to neurocognitive test performance. When considering this relationship, the first step was identifying foundations of concussion features. The actual diagnosis of a concussion may be made when a disturbance is registered in the cognitive ability of the individual after sustaining a traumatic force to the head or the body. The impact should inhibit ability to continue to play and therefore requires a professional opinion to determine if the

athlete would be ready to return to action and potentially suffer additional. Examples of mental change would be loss of consciousness, retrograde amnesia, anterograde amnesia, and confusion or disorientation.

Neurocognitive test performance and self-reported symptoms have not always been consistent constructs. Previous researcher found that symptoms reported alone identified 65% of concussed athletes, while 83% were identified via neuropsychological testing 2 days' post-concussion. When the symptom report and neuropsychological testing were combined there was a 93% identification rate of concussed athletes. It was acknowledged that the traditional route of neuropsychological testing via paper and pencil which can be time consuming and costly, and could not be administered in a group setting. As a prospect, the solution to this issue could be the use of group, computerized neurocognitive testing for the assessment of concussions and concussion management. The test offered a cost-efficient measure and could be administered in a timely manner, or approximately 25 minutes.

The most commonly used computerized neurocognitive test was proposed as the ImPACT. This test was found to have an 89.4% positive predictive value and an 81.9% negative predictive value. Research and testing suggested that the ImPACT could be a successful instrument in neurocognitive testing for concussion management. The referenced study examined the differences between the groups to determine any differences in test performance between participants that were concussed symptomatic, concussed asymptomatic, and control participants. The overall difference between the groups was significant in their scores on the six categorized tests of the ImPACT. The findings were concurrent with previous research, representing an imperfect relationship between symptom reporting and neurocognitive performance. This may be supported as an important finding since an athlete may be likely to underreport his or her symptoms in hopes to return to play sooner than advised.

**Kontos, Elbin, Covassin, & Larson (2010).** The ImPACT has been utilized for baseline testing, as well as for the assessment of concussions. It was suggested that there had been numerous studies to identify the differences in baseline test results as well as post-concussion test results between different age groups, but Kontos, Elbin, Covassin, & Larson (2010) sought to explore the differences between African American and Caucasian males. This information was suggested as important to clinicians testing athletes of different ethnicities in sporting contests since the assessment should be made to accommodate all races and gender. Previous research had been conducted to determine the differences in neurocognitive test results in regards to age, gender, learning disability, and concussion history. Albeit, there was a need to study other factors that may influence the results of neurocognitive testing.

Early studies had further indicated differences in psychological testing between Caucasian and African Americans. In regards to differences in neurocognitive testing, there has only been a difference in the memory subset between Caucasian and African Americans on the Test of Memory and Learning. However, using the Arizona Battery for Communication Disorders of Dementia, researchers found that Caucasian male and females scored higher on the Linguistic Expression component. Research advised that gender and race should not be studied alone and should be included with educational factors such as SES, reading level, and particularly educational background.

The present study used a sample of 48 Caucasian and 48 African American concussed high school and collegiate student-athletes. Over the course of the 2-year study, an athletic trainer or team physician was the person responsible for diagnosing the concussion. Each concussed athlete was administered the ImPACT at 2 and 7 days post-concussion. The participants did not differentiate on their scores in regards to baseline or post-concussion verbal memory, visual memory, reaction time, and total reported symptoms. There were no differences in baseline testing as well. This finding along with previous research suggested that the ImPACT could be culturally equivalent and effective in measuring neurocognitive performance, particularly across two racial-ethnic groups in the present study. The findings indicated that there should not be an equivalent test for other races or ethnicities besides the original ImPACT.

**Meehan et al. (2011).** Meehan et al. (2011) sought to investigate the prevalence of neurocognitive testing for concussions in the high school setting in the U.S. Computerized neurocognitive assessment was suggested as the preferred method of assessment, offering available, convenient, accurate, and sensitive assessments for athletes that may be high risk for concussion. It was reported that a previous survey of athletic trainers revealed that only 1.9% of the respondents completed neurocognitive testing when making return-to-play. Later on, further studies determined that only 16% of primary care respondents had access to neurocognitive testing within the week of a sustained injury. Furthermore, an additional referenced survey suggested that approximately 25% of high school sport-related concussions were diagnosed with the use of computerized neurocognitive testing towards the latter part of the 2000s. The High School Reporting Information Online (HS RIO) was the source for the gathered information in the referenced study. Any high school that employed an athletic trainer qualified for the study. The survey had a 97.3% response rate from 178 schools. Of the responding schools, approximately 40% utilized computerized neurocognitive testing in concussion management. Among the reported schools the majority utilized the ImPACT (93%). Over two-thirds of the schools that used computerized neurocognitive testing only tested certain sports. Greater than 85% of the schools performed both base-

line and post-injury tests. All schools reported using the results from the neurocognitive test as tool to determine if an athlete can return to play. In an academic year, the percentage of computerized neurocognitive testing rose from 25.7% to 41.2%.

With the growing rate of concussions and the support of the media, it was suggested that school were reaching out to professionals to aid in the decline of concussions and premature return to play. It was posted as difficult to determine an athlete's functioning if there was no baseline test to compare to the post-concussion results. The prevalence of computerized neurocognitive testing had risen; students were likely to understand that a lower baseline test score will be a way of limiting their chances of being diagnosed with a concussion and therefore not missing playing time. It is important to note that the ImPACT should be utilized with other clinical assessments such as symptoms reporting and postural control to increase diagnostic accuracy.

**Krol et al. (2011).** It was posted that with symptom reporting becoming critical to the assessment of concussions, an accurate reading should be utilized in every test. Symptom reporting could be influenced by many factors, including demographics, clinical, or methodological variables. Literature had stated that the social aspects of reporting symptoms, such as method and type of information, could have an effect of the accuracy of reporting. Specifically, information collected via interview could be subject to "interviewer effects" which may be based on the characteristics of the interviewer. This was suggested as importation to take into consideration when determining the symptoms of concussions from athletes directly.

Krol et al. (2011) examined the difference between symptom-reporting to an interviewer in contrast to simply a questionnaire in mild traumatic brain injury (mTBI). The questionnaire received approximately three times the average of the symptoms acquired in the interview. Krol et al. explored the differences in concussion symptoms obtained via questionnaire and symptoms obtained in an interview with the gender of the interviewer being the independent variable. Participants in the self-report group reported a greater total symptom score than participants in the interview group. There was a significant difference between the groups that were interviewed by a male interviewer as opposed to a female interviewer. Given these findings, it is important to consider the method of intake reporting symptoms in the overall assessment, and a comparable measure used at baseline and post-concussion.

**Schatz & Maerlender (2013).** According to Schatz & Maerlender (2013), the reliability, validity, and utility of the ImPACT, a computer-based neuropsychological test, for the purpose of the diagnosis, assessment, and management of sports-related concussions, had been consistently documented and debated in literature. With concussions remaining a popular topic in the

field of neuropsychology, the instruments of measurement should continue to be scrutinized. While there was continued skepticism about computer-based neuropsychological assessment for concussion, the ImPACT was purported to still represent the most widely-used measurement of sports-related concussions.

Authors reported that the ImPACT test had been developed over the course of its lifetime since 1999, originating as a file on Windows machines, to the online application through a web browser. The initial test generated three composite scores including memory, reaction time, and processing/visual motor speed. Visual memory and impulse control were introduced later on strictly for research purposes and not clinical purposes. The purpose of the present study was to validate the existence of a two-factor structure on the ImPACT (memory and speed) using composite scores, as well as evaluate the utility of the two-factor with respect to the ImPACT's reliability and validity.

The first study collected a baseline sample for the ImPACT of 21,357 middle school, high school, and collegiate athletes, with a mean age of 15.5. A concussion sample was obtained, composed of 560 middle school, high school, and collegiate athletes that completed a preseason baseline test, sustained a concussion, and were treated within seven days. The results of the first study concluded that the variance of factor analysis (verbal memory and visual memory as "memory", visual motor speed and reaction time as "speed") for the baseline group as well as the concussion group were almost identical (72.5% to 78.8%).

The second study analyzed 1-month, 1-year, and 2-year test-retest reliability. Intra-class correlation coefficients (ICCs) were calculated as an indicator of test-retest reliability. The ICC scores for memory and speed were both higher than the composite scores of the three samples that were analyzed. The two-factor composite scores yielded more reliable results than the use of individual composite scores. It was noted that concussed athletes shared higher levels of post-concussion symptoms, representing decreased variance relative to a wider range of post-concussion scores among memory and speed.

**Resch et al. (2013).** Resch et al. (2013) identified the potential test-retest differences. The study used two time intervals to see if the ImPACT would composite scores would reach an ICC value of 0.75 or higher. The two time intervals were tested in two different groups located in different countries. Approximately half of the composite score values fell below acceptable reliability for clinical interpretation. The ICC values in the second group were less than the other group, with the second group experiencing a longer time frame between the tests. This indication suggested that the reliability of the ImPACT decreases over time, therefore warranting more frequent baseline testing.

**McKay et al. (2013).** As stated by McKay et al. (2013), neuropsychological baseline testing is not only resource intensive, but also not always possible to be achieved. This could be an important matter to consider in the scope of ultimately completing a diagnosis, evaluating that baseline represents an essential feature toward identification to the diagnosis of a concussion. This particular study examined concussions among elite ice hockey youths. Concussions were reported to account for approximately 15%-18% of all injuries sustained within younger athletes. It was reported there may be a range of baseline tests that are population-specific, given that resources are limited in most clinical and athletic settings. When considering a baseline testing instrument, the tester needs to take into accounts that as adolescents increase in age, they similarly increase in cognitive ability, therefore performing better on neurocognitive tests. Although there are reported differences in scoring between sexes, the present study did not find related differences.

Again, the purpose of the present study was to determine population-specific reference values and psychometric properties of the ImPACT within elite youth ice hockey. It was also intended that information be presented in terms of clinical interpretation of composite and symptom scores. The baseline test was administered to the participants and took approximately 30 minutes to complete, yielding the five composite scores for visual memory, verbal memory, visual motor processing speed, reaction time, and impulse control. It was noted that the ImPACT also provides a total symptom score, based on the ratings of 22 post-concussion symptoms on a scale of 0 to 6. The baseline test did not yield any differences between sexes and the concussion history. The study produced the same results of the youth hockey groups as the average baseline collegiate baseline results. All composite scores fell within the average range as well. The only issue that the authors of the present study encountered was recall bias. That is, youth may not have been able to recall all of the concussion symptoms in their past in addition to their medical history.

**Covassin, Crutcher, & Wallace (2013).** Although it is recommended that the sustainment of a concussion may be assessed on the sideline immediately, it is also purported that the ImPACT may be utilized as a measure beyond immediate assessment. Typically, an athlete may experience several types of symptoms beyond the actual concussion, such as further cognitive, behavioral, sleep, and somatic symptoms for an extended period of time. During the post-concussion period, if an athlete partakes in a physical or cognitive activity, then it may be probable that their symptoms may worsen.

Covassin, Crutcher, & Wallace (2013) investigated the effects of a 20-minute cognitive task on the symptoms at 3- and 10-day periods post-concussion. While neuro-

cognitive assessment represents the leading method in diagnosing concussions, the present study was particularly significant. The objective was to examine if the concussion symptoms worsened immediately following the participants' performance on the ImPACT. A cross-sectional study design was utilized to compare the concussion symptoms from baseline, 3 days post-concussion, and ten days post-concussion. A total of 165 high school and collegiate athletes served as participants. Each participant was clinically diagnosed with a concussion; the athletes experienced a significant decline in their test performance after the 3-day period in each category (verbal memory, visual memory, reaction time, motor processing speed). On day 10 visual memory and motor processing speed scores both returned to baseline scores. More importantly, after 3 days post-concussion the athletes exhibited greater symptoms of headache, nausea, dizziness, sadness, mentally foggy and visual problems compared to the ImPACT test after the concussion was sustained. Therefore, the study showed that a neurocognitive test after the concussion does in fact prolong the symptoms. This is an important concept to consider, especially since that neurocognitive assessments following concussions represents the leading method for diagnosis. However, the study did take into consideration that the athletes were also attending school after the concussion.

**Ott, Schatz, Solomon, & Ryan (2014).** The ImPACT, as reported by the authors, was shown as a widely used instrument that must be diversified for different cultures and languages. According to the ImPACT developers, the test requires a 6th grade reading level to generate an accurate report on the diagnosis of a concussion. The ImPACT was reported to be at that time to be available in 21 different languages. According to the 2010 census, 16.3% of the population at the time of the study in the U.S. was Hispanic. The Census Bureau estimated that by 2050 the population will be 30% Hispanic, resulting in an increase of Hispanic athletes in the population. This prediction was predicted to increase the necessity of the ImPACT to be fully accurate and culturally adaptable.

Ott, Schatz, Solomon, & Ryan (2014) examined patterns in neurocognitive test performance between bilingual Spanish and English athletes as well as English-speaking athletes. The results revealed a significant difference between performances on the ImPACT with the Hispanic-speaking participants testing better in English but not remarkably improved than English-speaking participants. This information would be relevant for researchers and clinicians, considering such personnel administer and interpret the ImPACT across different languages and cultures, especially within persons with Hispanic descent.

**Meier et al. (2015).** With the ImPACT and neurocognitive testing and concussion management increasing in popularity, the possibility of falsifying results was

suggested to be a realistic concern. As discussed previously, reporting of symptoms represents an important feature of neuropsychological testing, considering symptom reporting accompanies concussion management. Whether an athlete reports their symptoms could be a determining factor in both diagnosis and treatment. Meier et al. (2015) sought to examine the environment in which athletes are more likely to report their symptoms appropriately. They compared self-reported symptoms in an onsite athletic facility versus a confidential research setting. Athletes completed the ImPACT at their athletic facilities under supervision of athletic trainers following a diagnosed concussion. Athletes also completed the ImPACT at a research institutes in confidentiality. To test for symptom reporting accuracy the Hamilton Anxiety Rating Scale and Hamilton Depression Rating Scale were also administered. Athletes in the athletic facility reported significantly fewer symptoms than those in the confidential research setting. The study supported the notion that there needs to be a better method of education for athletes and athletic trainers on the severity of concussions. An athlete must recognize the need to realize that sustaining a concussion and not properly treating it can lead to additional damage and possible longer time away from their sport. Ignoring the symptoms for purposes related to playing time can be detrimental to the athlete's career and future cognitive functioning. The underreporting of concussion symptoms must be addressed in all settings to ensure the safety of the athletes.

## Future Research Directions

There are several factors that should be taken into consideration when utilizing the ImPACT for future research. First and foremost, the validity of the test should be examined further. The incorporation of simulated malingering would be of great value during the administration of the baseline test when conducting research. The ImPACT has built in validity indicators, so there should be direct testing of these indicators. If athletes can manipulate their score on the baseline test to lessen their chances of being diagnosed with a concussion, then this raises a cause for concern. The main reason that an athlete would not want to be diagnosed with a concussion and play through it would be to increase their playing time for various reasons. Testing the ability of athletes to generate a sub average score would assist to further increase the validity of the ImPACT.

Secondly, the knowledge of concussions and concussion testing of the athlete should be taken into account in the initial baseline testing and interview results. If an athlete becomes aware of the purpose of the test and recognizes that it is for the betterment of their health, then this could lead to a better outcome for the overall testing and management of concussions. Incorporating a survey or Likert scale in the ini-

tial screening of the athlete could determine if athletes are familiar with the process and overall reason for a baseline test. If there is a need for proper education on concussions and concussion management, then there should be a broader education system for athletes and the importance of the detection and proper management for concussions.

## Conclusion

Sports represent a vital function to society. There has been evidence of better societal outcomes for people that participate in sports throughout their life. With the participation of sports, there is the fact that injuries will be sustained. The majority of contact sports injuries are closed head injuries that are happening at a growing rate. With the increasing prevalence of concussions, there is a greater need for testing and management of head injuries. The ImPACT has represented a main tool for concussion management and research in the last decade. This is evidenced by the research referenced previously. Future research should take into account the education that the athlete has received about concussions and concussion managements, as well as a continued effort to validate the ImPACT test as a whole. The implementation of simulated sub average performance would be ideal to test the current state of validity. If researchers can understand how a student-athlete can manipulate their test score, the progression of concussion testing and management will be more productive in the future.

## References

- Bailey, R. (2006). Physical education and sport in schools: A review of benefits and outcomes. *Journal of School Health, 76*(8), 397–401.
- Covassin, T., Crutcher, B., & Wallace, J. (2013). Does a 20 minute cognitive task increase concussion symptoms in concussed athletes? *Brain Injury, 27*(13-14), 1589-1594. doi:10.3109/02699052.2013.823656
- Epstein, J., & Klinkenberg, W. (2001). From Eliza to Internet: A brief history of computerized assessment. *Computers in Human Behavior, 17*(3), 295–314. doi:10.1016/s0747-5632(01)00004-8
- Fazio, V. C., Lovell, M. R., Pardini, J. E., & Collins, M. W. (2007). The relation between post-concussion symptoms and neurocognitive performance in concussed athletes. *Neurorehabilitation, 22*(3), 207–216.
- Kontos, A. P., Elbin, R. I., Covassin, T., & Larson, E. (2010). Exploring differences in computerized neurocognitive concussion testing between African American and White athletes. *Archives of Clinical Neuropsychology, 25*(8), 734–744. doi:10.1093/arclin/acq068
- Krol, A. L., Mrazik, M., Naidu, D., Brooks, B. L., & Iverson, G. L. (2011). Assessment of symptoms in a concussion management programme: Method influences outcome. *Brain Injury, 25*(13/14), 1300–1305. doi:10.3109/02699052.2011.624571
- McKay, C. D., Brooks, B. L., Mrazik, M., Jubinville, A. L., & Emery, C. A. (2013). Psychometric properties and reference values for the ImPACT Neurocognitive Test Battery in a sample of elite youth ice hockey players. *Archives of Clinical Neuropsychology, 29*(2), 141–151. doi:10.1093/arclin/act116
- Meehan, W. I., d'Hemecourt, P., Collins, C. L., Taylor, A. M., & Comstock, R. D. (2011). Computerized neurocognitive testing for the management of sport-related concussions. *Pediatrics, 129*(1), 38–44. doi:10.1542/peds.2011-1972
- Meier, T. B., Brummel, B. J., Singh, R., Nerio, C. J., Polanski, D. W., & Bellgowan, P. F. (2015). The underreporting of self-reported symptoms following sports-related concussion. *Journal of Science and Medicine in Sport, 18*(5), 507–511. doi:10.1016/j.jsams.2014.07.008
- Monroe, K. W., Thrash, C., Sorrentino, A., & King, W. D. (2011). Most common sports-related injuries in a pediatric emergency department. *Clinical Pediatrics, 50*(1), 17–20. doi:10.1177/0009922810378735
- Ott, S., Schatz, P., Solomon, G., & Ryan, J. J. (2014). Neurocognitive performance and symptom profiles of Spanish-speaking Hispanic athletes on the ImPACT Test. *Archives of Clinical Neuropsychology, 29*(2), 152–163. doi:10.1093/arclin/act091
- Perks, T. (2007). Does sport foster social capital? The contribution of sport to a lifestyle of community participation. *Sociology of Sport Journal, 24*(4), 378–387.
- Resch, J., Driscoll, A., McCaffrey, N., Brown, C., Ferrara, M. S., Macciocchi, S., . . . Walpert, K. (2013). ImPact test-retest reliability: Reliably unreliable? *Journal of Athletic Training, 48*(4), 506–511. doi:10.4085/1062-6050-48.3.09
- Schatz, P., Pardini, J. E., Lovell, M. R., Collins, M. W., & Podell, K. (2006). Sensitivity and specificity of the ImPACT test battery for concussion in athletes. *Archives of Clinical Neuropsychology, 21*(1), 91–99. doi:10.1016/j.acn.2005.08.001
- Schatz, P., & Maerlender, A. (2013). A two-factor theory for concussion assessment using ImPACT: Memory and speed. *Archives of Clinical Neuropsychology, 28*(8), 791–797. doi:10.1093/arclin/act077
- Simpson, D. (2005). Phrenology and the neurosciences: Contributions of F. J. Gall and J. G. Spurzheim. *Journal of Surgery, 75*(6), 475–482. doi:10.1111/j.1445-2197.2005.03426.x
- Snowman, J., & McCown, R. R. (2013). *Ed psych*. Belmont, CA: Wadsworth/Cengage Learning.