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A Review of ImPACT Testing Used for the Diagnosis of Concussion and the Influence of Language of Test Administration

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A REVIEW OF IMPACT TESTING USED FOR THE DIAGNOSIS OF CONCUSSION AND THE INFLUENCE OF LANGUAGE OF TEST ADMINISTRATION

by

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Abstract

The Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) battery is a widely used tool for the diagnosis and treatment of concussions. The purpose of this review was to evaluate studies that account for patient language and language of test administration when conducting ImPACT. A total of 36 articles were reviewed. The 36 articles reviewed accounted for English speaking populations and five of the articles accounted for populations representing different languages. Five of the studies were test-retest reliability studies. The results indicated that ImPACT has acceptable test-retest reliability when used in English to monolingual English-speaking participants. However, the results demonstrated ImPACT should only be implemented in populations that are not native English speakers under two circumstances: if participants complete a baseline and a post-injury test in the same language or if normative data is available for their native language. With data that includes language stratification limited primarily to the last ten years, this review also calls for more research to be done to determine how to best implement ImPACT in clinical settings.

Introduction

Diagnosis and Treatment of Concussions

Each year, in the United States alone, it is estimated that an average of 3.8 million traumatic brain injuries, called concussions, are sustained due to sport and physical activity (Broglio et al., 2014). The National Athletic Trainer's Association (Broglio et al., 2014) defines a concussion or a mild traumatic brain injury (mTBI) as forces that are applied to the skull resulting in an acceleration of the brain causing a change in the ionic balance and metabolism of the neural tissues there within. When this type of injury occurs, and presents with clinical signs and symptoms, the concussion diagnosis is made. Concussions are becoming one of the most prevalent injuries occurring in organized sport. A comparative study of nine scholastic sports

played in 100 US high schools found that concussions account for 9% of all injuries (Lincoln et al., 2011). Outside of the concussions acquired during sports, there are approximately 1.7 million additional concussions sustained in the United States every year. Because of the frequency of these injuries, it is estimated that approximately 5.3 million Americans are living with mTBI related deficits (Demery et al., 2010). Effective diagnosis and treatment of concussions is therefore crucial.

With so many cases of concussions happening both in and out of athletic settings, it is important to continue research into improving diagnosis and treatment by accounting for factors, both intrinsic and extrinsic to the patient that might affect treatment and cognitive testing outcomes. Intrinsic factors include things such as the patient's primary language, their education level, and presence of a learning disability. Extrinsic factors include things such as the time of day and where cognitive testing takes place. Some other possible confounding factors include how many hours of sleep the participant has gotten, the amount of caffeine they have consumed or if they have previously completed the ImPACT test. When these factors are not properly accounted for, they can negatively influence test outcomes and will invalidate the test. Because of this, steps are taken during the cognitive testing process to account for anything that could affect outcomes.

Cognitive Testing

Cognitive testing has become a widely-used tool in the diagnosis and treatment of concussions. Although cognitive testing is never used on its own but coupled with symptom tracking and motor-control assessment; it is a critical part of the diagnosis process. There are myriad cognitive tests used in various clinical settings, including Immediate Post-Concussion Assessment and Cognitive Test (ImPACT), Automated Neurophysiological Assessments Metrics

(ANAM), Cogstate Axon and Concussion Vital Signs (CVS). The most accepted of these tests for the diagnosis of concussions in athletic settings is the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT). The ImPACT is a computer based cognitive test that has three components and six cognitive tests. The three components of the test include demographic data, cognitive testing, and the post-concussion symptom scale. The six cognitive tests are designed to evaluate several aspects of cognitive function: attention, memory, processing speed, and reaction time (Jones et al., 2014) and the outcomes are displayed in five composite scores: verbal memory, visual memory, visual motor speed, reaction time and impulse control. Common practice for implementing ImPACT in athletic settings is to conduct baseline testing before participation and then compare scores after injury to those baseline scores. ImPACT is administered in a single session typically lasting approximately half an hour. The patient typically takes the computerized test in a room by themselves with distractions minimized to control for any extrinsic factors. This careful regulation of the testing conditions is necessary to control for confounding intrinsic and extrinsic factors.

Language

One important intrinsic factor that may need to be controlled for when evaluating patients of different backgrounds is the patient's native language. ImPACT was originally developed and tested in the United States in English and since then has been translated into 21 different languages in effort to be inclusive to different populations.

Although English remains the primary language spoken in the United States, the 2011 American Community Survey (ACS) reported that of the 291.5 million people aged five and over, 21% spoke a language other than English at home. Aside from English, the ACS distinguishes 39 different languages spoken in the United States broken into the four main

categories of Spanish, Other Indo-European Languages, Asian and Pacific Island Languages and All Other Languages. Of the number of people who reported they did not speak English at home, 58% of them still reported they spoke English "very well".

Bilingualism has been shown to have both advantages and disadvantages in cognitive processing. Advantages have been reported for tasks that require inhibition or similar executive functions. These advantages are linked to bilingual individuals' frequent need to inhibit responses in one language and favor the other language (Blake et al., 2015). On the other hand, disadvantages appear in language-processing tasks, regardless if the test is administered in the patient's native or secondary language. Even when tested in their native language, bilinguals tend to perform more poorly on language tasks when compared to monolinguals (Blake et al., 2015). Because these advantages and disadvantages may be present for bilinguals with specific types of cognitive activities, it is important to be aware the impact language can have on the outcome of cognitive testing.

Sports teams today are made up of individuals from a plethora of backgrounds and many different languages are represented. In 2010, it was estimated that 4.2% of Division I athletes identified as either Hispanic or Latino, making up the second largest minority group behind African Americans and in front of Non-Hispanics (Zgonc, 2010). Test-retest reliability for only English-speaking populations has been found acceptable in three studies: one by Resch et al. (2013), Nakayama et al. (2014) and Tsushima et al. (2014). Because it is possible that the language of test administration may invalidate cognitive scores this review will examine the results of studies using the ImPACT cognitive test that accounted for the language of the patient and the language of test administration. The information extracted from these studies will help

clinicians determine if accounting for language when administrating ImPACT is a practice that should be implemented to improve a score's validity and patient care.

Methods

Literature Review

This review of articles is a subset of a larger project in which all the available articles regarding concussions and cognitive testing were put into a database. The databases searched to find applicable articles included, but were not limited to, PubMEd, SportDiscus, PsycINFO, Academic Search Premier, CINAHL, MEDLINE and Psychology and Behavioral Science Collection. These databases were available through Utah State University's subscription to EBSCOHost. If the article was not available freely through the Utah State University Library, it was requested through interlibrary loan or accessed by colleagues at other universities or research institutions. The search terms used in the databases included concussion related terms ("concuss*" OR "mild traumatic brain injury" OR "mTBI" OR "closed head injury") and terms related to cognitive testing ("neurocognitive" OR "neuropsychological" OR "*cognitive" OR "*cognitive test").

Exclusion Criteria

All articles found through the search of databases were screened for primary inclusion by title. The articles considered for inclusion had to be original peer-reviewed work. Systematic reviews, meta-analyses, clinical descriptions, book chapters, consensus statements, dissertations or theses were all excluded. The articles were also excluded for any of the following reasons:

I. Only had access to obtain an abstract;
II. Animal studies;
III. Non-English manuscript;
IV. Used a non-group design;
V. There was no ImPACT testing;

VI. No specific test outcomes were reported; or
VII. No stratification by language

The initial search identified 1,258 articles related to concussions or mild traumatic brain injuries. These 1,258 articles were initially screened just based on the title. Then, the articles were screened for eligibility using the criteria above. The only articles included were those that used ImPACT testing and were stratified by language, which resulted in 36 included articles. The database search included articles published through 2017.

Results

When reviewing the articles, 36 out of 36 articles accounted for language of the participants in their study and the language of test administration. These 36 articles administered ImPACT in solely English or English and another language. When referring to Table 1, five articles used patients who spoke a language besides English and three of those articles administered the test in a language other than English. Five of the articles were test-retest reliability studies.

Table 1
Article Demographic Data

Article Authors	English Accounted For	Language Other Than English	Test-Retest
Alhilali et al., 2015	Yes	No	No
Allen et al., 2011	Yes	No	No
Blake et al., 2015	Yes	Yes	Yes
Brooks et al., 2016	Yes	No	No
Bruce & Echemendia, 2009	Yes	No	No
Bruce et al., 2012	Yes	No	No
Bruce et al., 2014	Yes	Yes	Yes

Echemendia et al., 2012	Yes	No	No
Elbin et al., 2011	Yes	No	No
Fakhran et al., 2014	Yes	No	No
Ghodadra et al., 2016	Yes	No	No
Henry & Sandel, 2015	Yes	No	No
Jones et al., 2014	Yes	Yes	No
Kontos et al., 2010	Yes	No	No
Kuhn & Solomon, 2014	Yes	No	No
Nakayama et al., 2014	Yes	No	Yes
Nance et al., 2009	Yes	No	No
Ott et al., 2014	Yes	Yes	No
Phillipou et al., 2014	Yes	No	No
Ponsford et al., 2011	Yes	No	No
Ponsford et al., 2012	Yes	No	No
Resch & Driscoll et al., 2013	Yes	No	Yes
Resch & Macciocchi et al., 2013	Yes	No	No
Resch et al., 2015	Yes	No	No
Schatz et al., 2012	Yes	No	No
Schatz & Maerlender, 2013	Yes	No	No
Schatz & Sandel, 2013	Yes	No	No
Shuttleworth-Edwards et al., 2008	Yes	No	No
Shuttleworth-Edwards et al., 2009	Yes	Yes	No
Tsushima & Siu, 2014	Yes	No	No
Tsushima & Geling et al., 2016	Yes	No	No
Tsushima & Siu et al., 2016	Yes	No	Yes
Yengo-Kahn & Solomon, 2015	Yes	No	No

Zuckerman & Lee et al., 2012	Yes	No	No
Zuckerman & Solomon et al., 2012	Yes	No	No
Zuckerman et al., 2013	Yes	No	No

The majority of the articles represented in this review only used English speaking populations and test administration in English. There are 28 articles that did not evaluate the test-retest reliability of ImPACT test outcomes or account for languages other than English and none of these articles were published before 2008. The publish dates show that research is still limited in this field but continuing to grow as researchers begin to include language stratification in their studies results to determine if language influences test outcomes.

In three articles, English-speaking only groups were used to determine the test-retest reliability when ImPACT was administered in English. The first study conducted by Resch et al. (2013) used 46 students from an Irish university and 45 students from a United States university. All participants completed ImPACT in English, at three different time points. Both the United States group and the Irish group had results that showed higher ICC (Intraclass Correlation Coefficient: a descriptive statistic used to show how strongly scores between testing sessions resemble each other) values for two of the composite scores, visual motor speed and reaction time and lower ICC values for the other two composite scores, visual and verbal memory. Group 1, the Irish group, had ICC values ranging from 0.26 to 0.88 for the four composite scores. Group 2, the United States group, had ICC values ranging from 0.37 to 0.76. Approximately half of these values fell below what is acceptable for reliability in the use of clinical decision making. 50% of the ICC values were acceptable for a 1-week testing interval. The conclusions found from this study further demonstrated that ImPACT has varying reliability when used in English-

speaking populations but when coupled with other components of concussion-management protocol, it is acceptable to use. (Resch et al., 2014)

Nakayama et al. (2014) had 85 college students complete ImPACT at three different time points. All 85 participants reported English as their primary language and they all completed the testing in English at all time points. All ICC's exceeded the threshold value of 0.60 for acceptable test-retest reliability and all cases fell within the 80% confidence interval for both RCI (reliable change indices) and RBM (regression-based methods). The study concluded that ImPACT is a reliable neurocognitive test at 45 and 50 days after the baseline assessment in English speaking populations.

Tsushima et al. (2016) examined 212 high school aged athletes to examine the two-year test-retest reliability of ImPACT. All the athletes were administered baseline tests, once before grade 9 and then again before grade 11. The results of the RBM analysis showed that the test-retest scores were stable as nearly all composite scores fell within 80% and 95% of the confidence interval. At present, there are no firm guidelines as to how often baseline testing should be performed however the results of this study show no significant differences between a two-year gap in testing so there would be no indication to perform a second baseline test. This means that athletes only need to be tested once before they sustain an injury, specifically when they are in the high school age bracket. The study also stated if an injury occurs and an athlete does not have baseline scores available, it is appropriate to employ normative comparisons when dealing with English speaking populations.

The test-retest reliability studies present in this review and were conducted with English speaking populations show that ImPACT is an acceptable tool to use when diagnosing concussions. The time points between tests show varying data, however, ImPACT has continued

to be the most widely used cognitive test because of its comprehensiveness. Being able to compare an athlete's post injury scores to their own baseline scores is ideal, but if that is not available, it is warranted to use normative comparisons (Nakayama et al., 2014). This data changes if the participants represented are not solely English speaking.

Shuttleworth-Edwards et al. (2009) compared a group of English-speaking predominantly white male athletes from the United States with an age-matched group from South Africa. The participants from South Africa, were from relatively advantaged English-African-speaking backgrounds. All participants completed the test in English. The results showed the South African participants outperformed the United States participants in reaction time but the South African participants had higher symptom scores. Overall the United States' normative data was similar to that derived in the South African participants who spoke English; meaning ImPACT administered in English is appropriate to use on South Africans but only those who speak English as a first language and who come from a relatively advantaged educational background. (Shuttleworth-Edwards et al., 2009)

Three of the studies used populations that were both English and Spanish speaking. The first completed baseline testing for 405 professional baseball players. (Jones et al., 2014) English was the first language for 304 of them and Spanish was the first language for 101 of them. When the results are not stratified for education level of the participants, significant differences existed in all composite scores except impulse control when native English speakers were compared to native Spanish speakers. However, when the results are stratified for education, the only differences noted are seen in reaction time and visual-motor speed. Therefore, the results of this study displayed that native Spanish-only speakers with a second language and college education have a lower baseline performance in certain components of ImPACT. Because all the native

Spanish college-educated subjects spoke English as a second language, their results could not be stratified by the participants' second language. The participants having a higher level of education did prove to minimize the difference in test outcomes. Overall under all testing conditions, the English-speaking group had higher composite scores meaning the Spanish-speaking group's scores could be invalid and misclassify their results as concussed when they are not in fact concussed.

Ott el al. (2014) also examined English and Spanish speakers in order to evaluate test outcomes scores and their validity by comparing a sample of 11,820 bilingual Hispanic athletes to a sample of 11,955 English speaking athletes. The bilingual athletes had the option of which language they wanted to take the test with 9,733 choosing to take it in English and the remaining 2,087 choosing to take it in Spanish. When looking at the language groups, Spanish-speaking athletes completing the test in Spanish scored more poorly on all composite scores than Spanish-speaking and/or English-speaking athletes taking the test in English. Also, Spanish-speaking athletes who completed the test in English scored more poorly than English-speaking athletes in all composite score outcomes except reaction time. Regardless of the language of test administration, English-speaking athletes had higher outcome scores than their counterparts. This study displays significant group differences across all three groups and shows that in the absence of baseline data for Hispanic athletes who complete ImPACT in Spanish, comparisons with normative data may result in misclassification of post-concussion scores.

The last English and Spanish comparison study was conducted by Blake et al. (2014) and used a group of 60 undergraduate university students in the United States. All the participants were bilingual English-Spanish speakers. Each participant completed the testing twice, once in English and once in Spanish. Language of administration was counterbalanced, half the

participants took the test in English then Spanish and the other half, Spanish and then English. 70% of the participants reported Spanish as their first language however between-group analyses revealed no significant effect of first language on any of the composite scores. The results of the testing showed significant differences when language of test administration was accounted for in verbal memory and visual motor speed but not for visual memory and reaction time. Spanish-English bilingual university students achieved higher verbal memory and visual motor speed composite scores when they completed the test in English rather than Spanish. This indicates that comparing post-concussion testing to baseline testing is only accurate when the two tests are completed in the same language. Comparing performances on the Spanish language version to English normative data will be invalid.

Bruce et al. (2014) examined the 1-year test-retest reliability in a multilingual group of 305 professional hockey players, representing seven different languages: English, French, Czech, Swedish, Russian, Finnish, and German. The athletes were instructed to take ImPACT in the language they felt most comfortable with and had to use that language for both sessions. The visual motor composite scores had marginal to high reliability across the language subsamples, with sICC ranging from .60 to .81. The reaction time composite scores also had marginal to high reliability with sICC ranging from .52 to .75. Verbal and visual memory composite scores generally had low reliability with sICC ranging from .22 to .58. When using .60 as an acceptable sICC value, these results show that the use of baseline and retest ImPACT scores might misclassify a percentage of athletes as cognitively normal when in fact they are still experiencing post-concussive cognitive decline. In addition, significant variability in test-retest reliability was found among the different language versions used in the NHL. The study's results were inconclusive when examining and comparing ImPACT versions in different language meaning

the translation from the original form of ImPACT in English might not be acceptable to use with participants who speak any other language.

Discussion

The purpose of this review was to evaluate studies that account for patient language and language of test administration when conducting ImPACT. This review summarized articles that included ImPACT composite scores stratified by patient language and language of test administration. The results demonstrated ImPACT has acceptable test-retest reliability when administered in English to monolingual English-speaking participants. On the other hand, the results show ImPACT should only be implemented in populations that are not native English speakers under two circumstances: if participants complete a baseline and a post-injury test in the same language or if normative data is available for their native language

When looking at the articles that only accounted for English speaking populations, it is apparent test-retest reliability is high and it is an acceptable practice to implement when using ImPACT. The three studies that evaluated test-retest reliability show acceptably high ICC, RCI and RBM values (Resch et al., 2013, Nakayama et al., 2014, & Tsushima et al., 2014). The time in-between the testing points appears to influence ImPACT scores (Tsushima et al., 2014) and there is no gold standard as to how long there should be in-between tests. Clinicians usually do not set the time period between tests instead they rely on the athlete's symptoms and how they are recovering from their injury to determine when testing is done during the treatment period. These test-retest reliability studies provide valuable information however they are not free from limitations. The limitations of these three studies include, the small sample size, the fact that the samples did not represent concussed groups and the time intervals between testing periods were vastly different. The small sample sizes limit the results from making conclusions about larger

populations. Not having concussed participants represented does not account for the symptoms these patients might be experiencing while injured that could influence their outcome scores. The varied time intervals between testing periods may increase the variability in test-retest outcomes. Introducing a standardized test-retest interval could prove to increase the validity and reliability of ImPACT outcomes.

The five studies that used participant populations who spoke languages other than English revealed ImPACT may not be appropriate to use for these populations (Shuttleworth-Edwards et al., 2009, Jones et al., 2014, Ott et al., 2014, Blake et al., 2014 & Bruce et al., 2014). Overall the data suggests ImPACT is only appropriate to use in other language groups under two circumstances; if the participant is administered the test in the same language twice to compare their own score's or if normative data is available for their language when they do not have baseline testing. If their composite scores are compared to the normative data of only English-speaking groups, their results might be misclassified and can change the course of their treatment.

Some of the differences seen in the composite scores could be accounted for because of a bilingual's need to inhibit the use of a one language in favor of another language. (Blake et al., 2015) Specifically this can negatively influence the reaction time scores. Research shows that bilingual's early training in switching back and forth between their languages leads to recruitment of brain regions involved in language control when performing cognitive tasks (Garbin et al., 2010). This means that no matter what language they may be taking the test in, their reaction time could be suppressed. The suppression of their reaction time could be attributed to needing more time to understand the instructions given or to comprehend the choices that are given on the screen (Garbin et al., 2010). On the other hand, the other composite

scores might see a boost as bilingual individuals have a greater comprehension of both languages and are able to process quicker than monolinguals. If these differences are not accounted for when looking at scores, ImPACT becomes invalid to use in these populations.

Two of the studies (Ott et al., 2014 & Bruce et el., 2014) reported results that showed even when bilinguals were taking the test in their native language, they displayed greater differences in their outcome scores. This observation indicates the translation from the originally written ImPACT test in English into other languages might not be inclusive and might not correctly represent outcome scores for patients of different languages. The five studies evaluated (Shuttleworth-Edwards et al., 2009, Jones et al., 2014, Ott et al., 2014, Blake et al., 2014 & Bruce et al., 2014) did not have enough data to determine if testing in other languages is conclusive and more research needs to be done evaluating the translation of the original ImPACT version.

Although this review reports evidence supporting the use of ImPACT in English-speaking populations, the data indicates that more research needs to be conducted when it comes to the use of ImPACT in languages besides English. Overall there is data that supports the use of ImPACT in different languages only when certain steps are taken to compare composite scores to a patient to their own baseline scores or the proper normative data. Although ImPACT has been translated into 21 different languages, normative scores are not available for these languages. ImPACT research that includes language stratification is fairly new, limited primarily to the last ten years as neurocognitive testing is becoming a critical part of concussion diagnosis and treatment. More studies on the influence of patient language and language of administration when conducting ImPACT testing could answer further questions.

Conclusion

In conclusion, ImPACT should only be implemented in populations that are not native English speakers under two circumstances: if participants complete a baseline and a post-injury test in the same language or if normative data is available for their native language. With data that includes language stratification limited primarily to the last ten years, this review also calls for more research to be done to determine how to best implement ImPACT in clinical settings. Knowing how language can influence outcome scores is crucial for health care professionals to know so that concussion patients are properly administered ImPACT and the scores are not misinterpreted.

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