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Research Article

Effect of Testing Language on ImPACT Scores in Non-Native English Speakers

Jennifer L Volberding[1]*, Ashley K Ziniel[2], Matthew S O'Brien[1] and Aric J Warren[1]

[1]*Department of Athletic Training, Oklahoma State University for Health Sciences, United States*

[2]*Department of Athletics, United States Air Force Academy Preparatory School, United States*

***Corresponding Author:** Jennifer L Volberding, Department of Athletic Training, Oklahoma State University Center for Health Sciences Tulsa, OK, United States.

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Abstract

As the diversity of collegiate athletes increases, identifying accurate ways to objectively evaluate concussions despite language and cultural differences is imperative to providing quality healthcare. ImPACT, Inc. is one of the most widely used methods to evaluate a concussion, thus the impact of language comprehension should be considered. To determine if native and English language scores differ on ImPACT scores in non-native English speakers and if differences are associated with previous English language exposure. Thirty non-native English speaking, undergraduate and graduate school subjects (8 male, 22 female, age = 24.4 ± 3.9 years) who reported no history of concussion participated in the study. Subjects' native language was required to be one of the 16 in which ImPACT is offered. Subjects completed the ImPACT test twice, first in English, then native language. Demographic information such as time spent living in an English-speaking country and formal English education was collected. ImPACT composite scores (Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control), cognitive efficiency index, and the total symptom score were used in a paired-samples T-test based on testing language, with correlations to identify relationships between difference scores and English exposure. Statistically significant differences were found for Verbal Memory ($t = -4.06$, $p = 0.00$), Visual Motor Speed ($t = -3.98$, $p = 0.00$) and the cognitive efficiency index ($t = -4.61$, $p = 0.00$) when comparing language. Correlations between magnitude of the difference and English exposure lacked significance. However, anecdotal evidence suggested some effect of language on total symptom score. Data reveals that participants scored higher in their native language than in English for several ImPACT composite scores, regardless of English exposure. Thus, individuals should test in native language whenever possible to provide accurate measures of neurocognitive function.

Keywords: *Baseline Testing; Concussions; Neurocognitive Function; Return to Play*

Abbreviations

ImPACT: Immediate Post-Concussion Assessment and Cognitive Testing; NCAA: National Collegiate Athletic Association; ISS: Office of International Students and Scholars; PI: Principal Investigator; VM: Verbal Memory; VMS: Visual Motor Speed; CEI: Cognitive Efficiency Index

Introduction

Concussions continue to be a major point of focus in the sports medicine community. An estimated 1.6 - 3.8 million sports-related mild traumatic brain injuries or concussions occur each year in the United States, with the majority of these being concussions [1,2]. Concussions can present with a variety of physical, emotional, and cognitive symptoms including headache, dizziness, irritability, sensitivity to light and sound, emotional distress, and neuropsychological impairment, making initial clinical presentation vary considerably from case to

case [1,3]. Beyond these initial symptoms, concussions can cause long-term cognitive deficits and can lead to Post-Concussive Syndrome, in which symptoms can often last longer than three months [3,4]. With such a high incidence and potentially serious short- and long-term effects, appropriate evaluation and management of concussions is essential.

Despite the importance of proper evaluation and management of this condition, there is not a consensus among sports medicine professionals as to how this is most effectively accomplished. There have been a multitude of studies conducted on this topic, yet researchers have failed to reach a definitive conclusion based on scientific research [1]. There are many types of evaluation and management tools; both paper and computerized versions, in existence including sideline assessment tools, balance tests, symptoms checklists and neurocognitive assessments [5,6]. Use of computer based neurocognitive assessments has been on the rise as head trauma experts and position statements from various healthcare groups have endorsed their usage [5,6]. One of the most widely used computerized tests for the evaluation and management of concussions is the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) system [1,5-7].

ImPACT was specifically designed to identify the effects of sport-related concussions on cognitive function [8]. In addition to initial evaluation, it is also used for tracking recovery [9]. The ImPACT test is a computerized neurocognitive test with both software and online versions that tracks symptoms and measures cognitive impairment. The test takes approximately twenty minutes to complete and consists of three sections. The first section collects demographic information and includes a health history questionnaire. The second section is a symptoms checklist, asking users to rate their current severity of twenty-two common concussion symptoms on a seven-point Likert scale. The third section is comprised of neuropsychological tests, taking users through six modules. These modules measure numerous aspects of cognitive functioning including: attention span; working memory; sustained and selective attention time; response variability; non-verbal problem solving; and reaction time. Scores are then automatically calculated by the software program and listed in a summary report [7].

To ensure the most effective use of neurocognitive tests, gathering pre-participation baseline measures is essential [4,7]. Establishing a reliable baseline measure is important for accurate, individualized comparisons with post-concussion test results [5,6]. It allows each individual to serve as his/her own control value and providing clinicians to ability to compare the individuals normal scores since many variables can affect the test outcome [5,9].

Although research has proposed that cultural and linguistic differences may affect neurocognitive test scores, differences when testing in other languages have not been studied [2-4,10,11]. While the ImPACT test is currently offered in sixteen languages other than English, the company ImPACT Applications, Inc. stated in an email (Personal Communication, April 11, 2013) that they have no research data regarding the differences, validity or reliability of the test when offered in another language. Furthermore, any relevant research involving ImPACT has failed to test a multicultural sample or has specifically excluded those who are non-native English speakers [2,3,5,11].

Over the past decade, the number of foreign athletes participating in National Collegiate Athletic Association (NCAA) sports has increased drastically, with the percentage of female athletes from foreign countries nearly tripling [12]. With increasing numbers of foreign athletes in college athletics, many of whom do not speak English as their native language, it is important to consider how this may affect ImPACT scores. Healthcare providers must be able to accurately evaluate and manage concussions in non-native English speakers in order to continue meeting a high standard of care for all English and non-English speaking patients. This study aimed to fill a gap in the existing literature by investigating the relationship between language and ImPACT results. To our knowledge, this is the first research study to investigate linguistic differences regarding the ImPACT test.

Materials and Methods

Participants

The subjects in this study were 30 (8 males, 22 females, 24.4 ± 3.9 years) healthy, non-native English speakers who were current students at a large southern university. In order to be eligible for the study, participants could not have had previous experience with the ImPACT test. The native languages of the subjects were one of the sixteen foreign languages in which ImPACT Applications Inc. offers the ImPACT

test (Portuguese, Swedish, Norwegian, German, French, Spanish, Italian, Czech, Russian, Mandarin, Finnish, Afrikaans, Hungarian, Korean, Japanese and Cantonese). The native languages of the subjects used for testing are shown in table 1. Exclusion criteria for participation in the study included current illness and/ or a history of concussion within the previous five years. If a subject sustained a concussion or other head injury during the two-week period between testing sessions or became acutely ill, his/her scores were not included in data analysis. The institutional review board approved the study and all subjects were required to sign a consent form indicating the voluntary nature of their participation in the study and their understanding of the study's methods prior to data collection.

Procedures

Potential subjects who were international students at the institution were contacted with assistance from the Office of International Students and Scholars (ISS). The manager of the ISS Office sent an invitation email on behalf of the primary investigator (PI) to international students via their listserv. In the invitation email, interested students were directed to respond to the PI via email and

Language	Number
Spanish	10
Mandarin	7
Portuguese	2
Korean	2
Czech	2
Norwegian	2
French	2
Russian	1
Swedish	1
Japanese	1

Table 1: *Native language of subjects.*

asked to complete a pre-participation eligibility questionnaire regarding age, native language, history of concussion and their current health status. Potential subjects meeting eligibility requirements were assigned a time to complete the first session of testing. On their test date, subjects were asked to sign an informed consent form and fill out a pre-test questionnaire that was used to collect information about the number of years they have lived in an English-speaking country and/or taken formal English classes. Subjects then completed the ImPACT test (version 2.1) either individually or in a group in a proctored, quiet, controlled environment where outside distractions were minimized. ImPACT states that the non-English versions are direct translations from the English version and did not incorporate any additional interpretation [7]. Subjects completed the first round of testing in English and were asked to complete the test prior to asking any questions. Upon completing the first test, subjects were asked about their experiences with the test by the test proctor. Anecdotal information was collected at this time, but subjects did not receive any feedback or other information regarding the completed test. Subjects were then asked to schedule second the follow-up test. The subjects returned approximately two weeks later to complete the ImPACT test in their native language. Before the second test, they verified that they were not acutely ill and had not sustained a head injury since taking the initial ImPACT test in English. Anecdotal information was again collected upon the completion of the test in the subject's native language. Following the second round of testing, score reports were generated and used in data analysis.

The order of the tests was not randomized due to the authors' intention of determining the impact of the English test on non-native English speakers. The authors' felt exposure to the test in the native language may have impacted the English scores even though the two-week period has shown a minimal practice effect [8,13]. The two-week testing period was selected secondary to its use in previous research. Due to the fact the test is computerized, it is able to minimize practice effects through the use of multiple forms and random organization unlike other neurocognitive tests [5,7,8]. This is important to control for practice effects in a concussion management tool,

as it is administered numerous times over a short period time [5]. In a study on version 1.0 of ImPACT, it was observed that over a two-week period a practice effect did not occur, while another found a minimal practice effect on the processing speed (visual-motor speed) composite but no effect on the other reported scores [8,13].

Data analysis

Data analysis was completed using the five composite scores generated by the ImPACT test: Verbal Memory; Visual Memory; Visual-Motor Speed; Reaction Time; Impulse Control. In addition, analysis included the variables of Cognitive Efficiency Index score and the Symptom Score Composite. For each of the seven scores, a paired samples t-test was used to determine if any significant differences exist between the test scores from the English test and the test scores from the subjects' native language test. Difference scores were then calculated for each of the subjects' seven scores by subtracting the English test score from the native language test score. A correlation analysis was performed to identify potential correlations between the number of years the subject has spent in an English-speaking country and/or the number of years of formal English classes and the magnitude of the difference score. Difference scores were included in the analysis so that each subject served as his/her own comparison to minimize confounding variables. A post-hoc one-way ANOVA was conducted to determine if there was an interaction between sex and magnitude of the difference score for each of the seven variables.

Results

ImPACT Results

The purpose of this study was to determine if a difference exists between ImPACT scores when non-native English speakers complete the test in English versus when taking the test in their native language. The ImPACT test reports generated five composite scores representing different areas of cognitive functioning: Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control. These five composite scores along with the Cognitive Efficiency Index and the Symptom Score Composite were analyzed to identify differences between the English test scores and the native language test scores. The Cognitive Efficiency Index is a number calculated by ImPACT based on the interaction of speed and accuracy in the subjects' performance on the Symbol Matching task. Of the seven score comparisons, statistically significant differences were found in Verbal Memory, Visual Motor Speed, and Cognitive Efficiency Index. Results for the paired samples comparisons are shown in table 2.

Variable	Language	Mean	St.D	95% CI of the Difference	t	p
Verbal Memory	English	82.10	8.72	-10.43, -3.44	-4.058	.000
	Native	89.03	9.53			
Visual Memory	English	71.20	13.00	-6.70, 4.50	-0.402	.691
	Native	72.30	14.71			
Visual Motor Speed	English	39.51	5.68	-4.28, -1.37	-3.982	.000
	Native	42.33	6.97			
Reaction Time	English	0.59	0.08	-0.03, 0.01	-0.677	.504
	Native	0.60	0.08			
Impulse Control	English	5.10	4.35	-0.79, 1.26	0.467	.644
	Native	4.87	4.09			
Cognitive Efficiency Index	English	0.26	0.12	-0.16, -0.06	-4.607	.000
	Native	0.37	0.14			
Symptom Score Composite	English	16.30	20.96	-0.86, 8.12	1.655	.109
	Native	12.67	16.37			

Table 2: *Paired Samples t-test, N = 30.*

The mean Verbal Memory score was 82.10 ± 8.71 in English and 89.03 ± 9.53 in subjects' native language. The t-value for this comparison was -4.058, with a significance of p = 0.000. This showed a statistically significant difference in Verbal Memory score between the two

languages ($p < .05$). For this comparison, there was an effect size of $r = 0.61$ and a power of 0.99. A second score that showed statistical difference was Visual Motor Speed, which had means of 39.51 ± 5.68 in English and 42.33 ± 6.99 in the native language. With a t-value of -3.982 and a significance of $p = 0.000$, the difference between the scores reached statistical significance ($p < .05$). The Visual Motor Speed difference had an effect size of $r = 0.60$ and a power of 0.99. In addition to the differences found for these two composite scores, we also noted that there is a significant difference for Cognitive Efficiency Index ($p < .05$). The mean score for Cognitive Efficiency Index in English was 0.26 ± 0.12 and in subjects' native language was 0.37 ± 0.14. This produced a t-value of -4.607 and a significance of $p = 0.000$. The effect size for this score difference was $r = 0.61$ with a power of 0.99.

The Symptom Score Composite, based on subjects' experience of 22 common concussion symptoms, had a mean of 16.30 ± 20.96 for the English test and 12.67 ± 16.37 for the native language test. The comparison lacked significance ($t = 1.655$, $p = 0.109$) however, anecdotal evidence from this study suggests some effect of language on symptom score reporting. Numerous subjects approached the researcher with questions regarding the meaning of certain words used to describe the symptoms during the English testing. The most common symptom descriptions that subjects either did not recognize or did not understand in English were "dizziness" and "drowsiness". These symptoms were scored as a zero on a seven-point Likert scale (0 - 6) of frequency and intensity of symptom experience by subjects who did not understand the description.

English exposure results

The secondary purpose of this research study was to determine if there is a relationship between the score in English on ImPACT and the amount of exposure that a subject has had to the English language. After difference scores were calculated by subtracting the English test score from the native language test score, analyses then set to identify potential correlation to the number of years a subject had lived in a primarily English-speaking country and to the number of years of formal English education that a subject possessed. The mean number of years that subjects had lived in a primarily English-speaking country was 3.00 ± 3.49 years and with a mean of 7.42 ± 4.04 years of formal English education. Means and standard deviations for each of the difference scores used in determining correlation are shown in table 3.

English Language Scores	Years Living in English-Speaking Country	Years of English Education
Verbal Memory	-0.129	0.270
Visual Memory	-0.169	0.274
Visual Motor Speed	0.117	0.129
Reaction Time	-0.146	0.021
Impulse Control	-0.040	-0.254
Cognitive Efficiency Index	-0.324	0.142
Symptom Score Composite	0.009	0.243

Table 3: *Pearson Correlation Coefficient Values of English Language Scores to English Exposure, N = 30. *Statistically Significant Correlation (p < .05).*

The amount of difference in score from English test to native language test failed to reach statistically significant correlation ($p < .05$) with the number of years living in an English-speaking country for each of the seven measures with which analysis was conducted. We also failed to find a correlation between these seven difference scores and the number of years of formal English-language education that subjects had before residing in a primarily English-speaking country ($p < .05$). Results are presented in table 3. According to this study's data, there lacks a significant relationship between exposure to English and the magnitudes of the differences between English scores and native language scores.

Gender

Post-hoc analysis was conducted to look for an effect of gender on the magnitudes of the differences between English language test scores and native language test scores. A one-way ANOVA was performed on the five composite scores measuring cognitive functioning

along with the Cognitive Efficiency Index and the Symptom Score Composite. The results failed to discover any interaction between gender and score differences ($p < .05$), as seen in table 3.

Discussion

The goal of this study was to investigate the effect that language has on scores of the ImPACT test, a neurocognitive assessment used for concussion evaluation and recovery tracking, in persons who are non-native speakers of English. With increasing numbers of foreign-born student-athletes participating in NCAA sports and the importance of proper concussion management, determining the most accurate and reliable way to evaluate concussions despite language differences is essential [12]. In a broader sense, considering how language and cultural factors affect numerous areas of athletic healthcare is vital to athletic trainers and physicians working with these individuals and this study aimed to explore one aspect of this interaction.

The results of this study demonstrate that testing language does have an effect on ImPACT scores for those whose native language is not English. Two of the five composite scores representing cognitive functioning, Verbal Memory (VM) and Visual Motor Speed (VMS), demonstrated differences between English and the native language test. The Cognitive Efficiency Index (CEI), which is calculated based on a subject's speed and accuracy during the Symbol Match module, also demonstrated a difference that is considered statistically significant [14]. These results indicate that language plays a role in cognitive function as measured by the ImPACT test beyond tasks explicitly measuring verbal cognitive abilities. This agrees with previous studies that have proposed that language and cultural differences may influence neurocognitive test scores [2-4,10,11].

The manner in which VM, VMS, and the CEI are scored by ImPACT provides some insight into the interaction between verbal and non-verbal cognition and helps explain why language differences can affect non-verbal tasks as well. The VM score is based on a subject's performance on three different modules during the ImPACT test: word memory, three letters, and symbol match. The three letters task is also one of the two tasks used to determine the VMS composite score [14]. Thus, language differences causing a change in performance on this task would affect VM and VMS scores. The symbol match module, in addition to composing one-third of the VM score, is also the sole determinant of the CEI [14]. A change in performance on this task would coincidentally result in changes to both of these scores. Since one of two tasks determining the VMS score and the task used in CEI scoring are also used in calculating VM, we propose that these tasks involve some level of verbal cognition in addition to the non-verbal aspects.

Findings in this study suggest a verbal component to non-verbal cognition, as the difference in testing language affected numerous ImPACT scores in this study's non-native English speaking population rather than just verbal memory. As language is one important aspect of culture, this finding agrees with earlier research indicating a link between culture and non-verbal skill performance on cognitive tests [15]. Neurocognitive assessments of non-verbal and visual-spatial tasks are still culturally dependent, with some research finding a larger cross-cultural difference on these tasks than on verbal tasks [15]. Since ImPACT was developed in the United States, considering the effect of language and culture on test performance for foreign-born student-athletes is crucial [11]. Testing in their native language whenever possible can eliminate language difference as a factor that can skew test scores.

Data analysis revealed that the score on the English ImPACT test and the English test and the native language test did not correlate with either of the indicators of English-language exposure used in this study: years of residence in a primarily English-speaking country and years of formal English education. Despite research indicating significant gains in second-language comprehension during the first few years of education and/or living in a country with it as a primary language [16], the differences in ImPACT scores were not influenced even though the average time of residence in an English-speaking country was three years and the average amount of education was nearly seven and a half years. The lack of relationship between score difference and English exposure reveals that dissimilarities in scores on cognitive functioning measures based on testing language remain significant, even in subjects who possessed more years of experience with English as a second language. Considering this issue, obtaining baseline measures of true cognitive function on neurocognitive tests for non-native English speakers may not be possible when tests are conducted in English; accurate baseline scores require testing in a person's native language.

While the difference in the Symptom Score Composite based on testing language did not reach statistical significance, there was anecdotal evidence from the study supporting earlier research that establishes an effect of culture and language on both symptom experience and symptom reporting [3,11]. A study conducted by Zakzanis and Yeung [3] noted an effect of culture on pain perception, behavior, and manifestation of stress. Another study, which specifically investigated the ImPACT symptoms checklist, found a clinically relevant change in composite score amongst English-speakers from two different cultures. The authors speculated that a difference in symptom terminology interpretation may have been an influential factor [11]. Research on experience of concussive symptoms across four different cultural groups discovered differences in symptom incidence and severity. These researchers concluded that the presence or persistence of certain symptoms during post-concussion assessment may simply be due to cultural and linguistic differences [3]. With this, failure to understand certain terms on the symptom checklist or differing interpretations of the terminology may affect symptom reporting in non-native English speakers, a difference that would more likely be seen during post-concussive testing when test-takers would be more likely to experience the symptoms.

Limitations and Future Research

Several limitations existed within the study. Firstly, there is an inability of the researchers to ensure that subjects were putting forth complete effort during testing and being honest regarding symptom experience. To adjust for this potential issue, healthy subjects with no apparent motivation to skew results with poor effort or be deceptive regarding their symptom levels were included in the study. Secondly, ImPACT Applications, Inc. admits there is no data regarding the reliability or validity of their test when conducted in a foreign language (Personal Communication, April 11, 2013). This limits interpretation and generalizability of the results of the study. In addition, the small subject size served as a limitation; not all of the foreign languages that are offered by the ImPACT test were used during research. Thus, our ability to generalize our results to all languages beyond those used in this study is limited.

Based on the limitations of the current study, the researchers propose that the study be repeated with a larger subject size with a randomization of the tests. In addition to providing further validation for the results found in the present study, it may allow for more of the available languages to be evaluated. In turn, more information can be ascertained regarding each particular language and its effects on ImPACT scores versus English testing. It is possible, for instance, that a larger difference in scores may be observed with languages that do not use the English alphabet since speakers of those languages may not be as familiar with the English letters. This may affect accuracy or speed during certain modules such as the Three Letters task.

Another area for future research concerns the long-term stability of ImPACT scores in foreign language testing. Research on ImPACT when taken in English has shown no substantial change in baseline scores when retested four months, one year, and two years later [5,6]. Since ImPACT Applications, Inc. does not have reliability data on their foreign language tests (Personal Communication, April 11, 2013), research to establish baseline score stability should be conducted.

This investigation involved studying differences between English language testing and native language testing for non-native English speakers in healthy subjects only. While a difference was found in baseline scores, further research should look at the magnitude of score difference between the two languages in subjects during post-concussive testing. It is possible that cognitive impairment due to the presence of a concussion could exacerbate any existing score difference. As previously mentioned, there may also be a larger magnitude of difference in Symptom Score Composite since subjects are likely to be experiencing more of the symptoms or at a greater intensity.

While the results of this study show an effect of testing language on scores of the ImPACT neurocognitive test in non-native English speakers, we are unable to generalize our results to any other concussion assessments. Our findings suggest that testing language may also affect scores on various other assessment tools, such as the SAC, the SCAT-3, and other computerized neurocognitive tests. With a lack of research in this area, we advocate for further studies investigating the role of language in concussion testing for non-native English speakers. This could also be projected out to the broader provision of healthcare for student-athletes with varying linguistic and cultural backgrounds. Research should focus on finding ways to improve cultural competence of athletic healthcare providers in order to provide the most more effective healthcare care for a diverse population of student-athletes.

Conclusion

Based on the results of this study, we propose an important clinical recommendation for baseline ImPACT testing of student-athletes for whom English is not their native language. Due to differences in ImPACT scores between the two testing languages, individuals should be tested in their native language whenever possible however, this would be limited to those who speak one of the sixteen foreign languages in which ImPACT is currently offered. Conducting a test in a foreign language is accomplished when the test is accessed through the ImPACT Applications, Inc. Customer Center website; any language that is currently offered may be selected at the beginning of the test. Purchase of any ImPACT testing package allows access to the test in these additional languages; no separate purchasing is required. As there is no additional cost for the foreign language tests, testing non-native English speakers in their native language is feasible regardless of budgetary or time concerns. There should be few, if any, barriers to implementing native language testing for those whom it is appropriate.

The recommendation to test in the native languages of student-athletes persists regardless of how many years they have been living in an English-speaking country or taking English educational courses. If a test-taker considers a language other than English to be his or her native language, the test should be administered in that language if it is offered by ImPACT. Even though subjects in this study had a significant amount of experience with the English language, the fact that score changes between the English and native language tests were found illustrates that these differences are not eliminated even after years of English exposure. In terms of baseline testing, this indicates that there is no threshold or "cut-off" point in terms of language exposure amount, after which testing in English will provide an accurate measure of cognitive functioning.

Even though this study failed to find a significant difference in Symptom Score Composite between the two testing languages, anecdotal evidence and previous research suggest that clinicians should understand the effect that language may have on symptom reporting, especially in non-native English speakers. With symptom scores directly affecting return to play decisions after a student-athlete experiences a concussion, it is important to consider how a lack of English language proficiency or symptom description familiarity may influence symptom reporting. Athletic trainers and other healthcare providers administering baseline or post-concussive testing should be aware that student-athletes who do not understand a word used to describe a symptom may score it as a zero regardless of their actual experience of the symptom. For this reason, every effort should be made to have student-athletes take symptoms inventories in their own language, such as the one offered as part of the ImPACT test or have someone available to explain what is meant by a symptom description if the test is taken in English.

With the number of collegiate student-athletes from increasingly diverse backgrounds participating in athletics, including speaking a primary language other than English, this study set out to determine the effect that testing language has on scores of the ImPACT test in non-native English speakers. Results from the present study demonstrate a significant difference in scores based on the language in which the test is administered so we propose that non-native English speakers should be tested in their native language whenever possible. In addition to providing a more accurate description of cognitive ability, it allows clinicians to provide a more culturally aware healthcare service based on an individual student-athlete's linguistic background. With concussions having potentially serious long-term complications if not assessed or monitored appropriately, ensuring that baseline neurocognitive assessments are valid and reliable is of the utmost importance.

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Conflict of Interest

The authors do not have any conflicts of interest to declare for this study.

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