**Reporting on Diversity in Concussion-Focused Neurocognitive Research: A Demographic Review**

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**Abstract**

**Importance:** Clinical diagnosis of concussions involve a multi-faceted approach, including assessments of symptoms, neurocognitive status, posture, behavior and sleep. Broadly, both healthy and concussed individuals from culturally and linguistically diverse populations demonstrate performance at levels lower than similar White, English-speaking cohorts on common neurocognitive tests. The purpose of this literature review was to determine the prevalence of demographic reporting with respect to race, ethnicity/culture, and language in the context of concussion-related neurocognitive testing.

**Observations:** A systematic search of the literature yielded 768 unique citations reporting concussion-related neurocognitive outcomes. Of these, 36.07% (n = 277 articles) included at least one participant demographic distribution for race, culture/ethnicity, or language. However, only 1.8% (14 articles) included one or more demographics in the data analyses.

**Conclusions and Relevance:** These findings indicate limited external generalizability for the majority of the included articles. Additionally, differences between racial, cultural/ethnic, and linguistic groups are not fully explored and caution is warranted for clinical interpretation of neurocognitive test outcomes when used with diverse populations.

**Introduction**

Concussion diagnosis and management is an issue of social and medical emphasis. 1.7 to 3.8 million mild traumatic brain injuries (mTBI), of which concussions are a subset, require hospitalization each year and countless concussions, including sports-related concussions, are managed clinically or go undiagnosed.1–3 Furthermore, individuals participating in all sports at all competition levels are at risk for concussion, with the highest degree of risk found for collision/contact sports (i.e. football, hockey soccer).4 Concussion management is also a research emphasis for the military, as both blast-related and blunt-trauma concussions are prevalent for deployed military personnel.5 Although sports- and military-related concussions receive the media coverage, the majority of diagnosed mTBIs result from motor vehicle accidents.1,6,7 Therefore, concussion is not merely a sports/military issue, but one affecting all members of society.

In the current recommendations for the diagnosis and management of concussions, a multidisciplinary team is responsible for evaluating the individual for symptoms and functional deficits.8,9 Within each discipline, multiple measures may be employed to inform this clinical team, including symptom reports and assessments of neurocognitive and behavioral function, postural stability, and sleep. Given that individuals from all cultural and linguistic backgrounds are at risk for concussion, the need for clinically- and culturally-relevant, valid measures is imperative.

This is especially true for neurocognitive testing in light of several facts. First, many common neurocognitive tests were developed for, and validated on, White, English-speaking individuals in the United States.10,11 As such, test performance by other racial, cultural, ethnic, and linguistic groups may differ from the expected outcomes for reasons other than cognitive impairment, including education, cultural salience, and acculturation.12–14 Consequently, there is reasonable evidence indicating that neuropsychological tests contain cultural biases12,13,15,16 resulting in potential misdiagnoses.17–20 These issues are exacerbated when examiners and clients speak different languages.12,14,20–22 Finally, global immigration trends indicate that, as of 2015, 244 million individuals worldwide reside outside their country of birth.23 Thus, in both research and clinical practice, cross-cultural neuropsychological testing is one that affects clinicians, patients, and participants regardless of the country in which testing occurs.

**Purpose and Organization**

The purpose of this literature review is, therefore, to determine the extent to which cultural and linguistic demographic data are reported for neurocognitive outcomes in concussion-related research. To do so, first a definition and brief overview of concussion will be provided along with characteristics of common testing methods. Second, a brief overview of the evidence for the impact of race, culture/ethnicity, and language in cognitive function will be presented. Third, an overview of the literature regarding racial, cultural, and linguistic reporting in concussion-related neurocognitive testing will be given. Finally, conclusions will be offered along with recommendations for future research and clinical considerations.

**Concussion Overview**

Concussion is a consequence of direct (applied to the head itself) or indirect force (applied to the body and transferred biomechanically to the head) resulting in disrupted brain function.8,24,25 Broadly, disruptions include impairments or changes in cognitive status, behavior, balance, sleep and the presence of somatic symptoms (most commonly headache, photo-/phonosensitivity, nausea, vomiting, confusion or fogginess, and dizziness).8,9,24,25 Symptoms often present uniquely, such that the same incident yields severe symptoms in some and seemingly no symptoms in others.26,27 Therefore, the diagnosis and management of a concussion is confounded by the multitude of ways in which symptoms may present.

Furthermore, concussion is a clinical diagnosis.8,9,24,25 Neuroimaging generally fails to reveal acute structural insults to the brain and is therefore not commonly used.8,28 Accordingly, injury mechanism, clinical presentation, and formal testing are the current centerpieces of concussion diagnosis.8,24,29,30 Symptom scales, neurocognitive tests, and balance assessments are commonly utilized to provide as part of a comprehensive evaluation of the individual.31–37 Many tools have previously demonstrated validity, reliability, sensitivity, and specificity in multiple samples in the United States.37–41

The more common neurocognitive tests for post-concussion assessment – including the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), CNS Vital Signs, as well as more traditional tests including Trail Making Test and Stroop tests – evaluate the domains of cognition most commonly affected by a concussive event, including memory, concentration, executive function, information processing and reaction speed.31,42–47 Domain-specific impairments are reported acutely after injury and generally return to pre-injury performance levels within 3 weeks of injury.31,45,48,49 However, persistent deficits have been reported in some individuals long after the clinical resolution of symptoms.50–52

These tests are often used to measure function prior to a competitive season or series of seasons. In the event of a concussive injury, data are then used for comparison with post-concussion data collected at specific time points. In the absence of baseline measures, normative values exist for many of these tests. However, normative values are generally based on predominantly White, middle-to-upper class, English-speaking high school and college students in the United States and may lack sensitivity to racial, cultural/ethnic or linguistic differences when applied to other populations.53–56 This is undoubtedly problematic when establishing return to “baseline” after injury for individuals not captured in normative datasets.

**Racial, Cultural/Ethnic and Linguistic Impacts on Cognitive Tests**

Few studies have examined the specific effects of race, culture/ethnicity, or language on neurocognitive testing for concussion management. Kontos et al42 compared African-American and White athletes’ performance on the ImPACT at baseline, two, and seven days post-injury. The authors noted that African-Americans were more likely to demonstrate a significantly decline cognitive function at one week post-injury with a similar trend at two days post-injury. Specifically, the authors observed decreased motor processing speed in the African-American group and a lack of practice effect from baseline to seven days post-injury. The authors suggest that the lack of differences at baseline between the groups, coupled with the fact that differences were observed in only one measure, does not merit a separate normative baseline for African Americans. However, participants in this study were all English-speaking high school and college students from similarly performing academic institutions. Consequently, these participants may not represent the breadth of educational, acculturation, linguistic, and socioeconomic conditions, which may impact individuals’ pre- and post-injury test performance.

Likewise, Shuttleworth-Edwards et al56 compared white, English-speaking football players in the US to predominantly white English-speaking rugby players in South Africa on the ImPACT. The South African players tended to report higher symptom scores though cognitive task outcomes were similar. However, the authors acknowledge that the athletes in both groups were predominantly White and well-educated.56 The similarity of these results may not persist outside of this narrow scope.

Some cross-lingual comparisons have been conducted. Ott et al55 compared English-speaking athletes to Spanish-English (native Spanish speakers with English as a second language) bilingual athletes taking the ImPACT in either Spanish or English. Bilingual athletes completing the ImPACT in Spanish performed more poorly than both bilingual and English-speaking individuals taking the test in English. Furthermore, bilingual athletes taking the test in English performed more poorly than English-speaking athletes. The authors note that this study highlights the need for caution when administering the ImPACT to Spanish- and English-speaking Hispanics.55

In short, racial and ethnic background, cultural heritage, and primary language likely influence neurocognitive testing outcomes following concussion.12–20,22,42,55,56 The purpose of this review is therefore to determine whether these important demographic features (e.g. race, culture/ethnicity, and language) are being reported in conjunction with concussion-related neurocognitive testing, and then identify to what extent they are factored into the analysis and interpretation of concussion-related neurocognitive outcomes.

**Methods**

**Search strategy**

A multiple database search was conducted on the following databases: Academic Search Premier, PsycInfo, CINAHL, MEDLINE, SportDiscus, and Psychology and Behavioral Science Collection (all available through EBSCOHost at Utah State University) in March, 2016. Search terms for all databases included terms related to concussion (“concuss\*” OR “mTBI” OR “mild traumatic brain injury” OR “closed head injury”) and terms related to neurocognitive testing (“\*cognitive” OR “\*cognitive test”). Only articles published in English were considered. No restrictions on year of publication were imposed.

These search procedures yielded 4961 citations, of which 2541 were unique citations. Titles and abstracts were screened for inclusion based on the following guidelines: Articles reported on:

1. Original (no systematic reviews, meta-analyses, book chapters, or consensus statements), peer-reviewed (no dissertations or theses) manuscripts. Articles published ahead of print were included.
2. Specific neurocognitive or neuropsychological tests. Articles were included if specific test outcomes were reported, if test scores were used to stratify individuals into groups (e.g., post-concussion syndrome (PCS) or no PCS), or if test scores were entered into a model and reported as coefficients rather than specific values.
3. Human participants in a concussion context. Concussion context included studies reporting on acutely concussed individuals, the long-term effects of previous concussions, test-retest reliability for concussion-specific cognitive tests (e.g., one-year test-retest reliability, repeat baseline assessment) within non-concussed populations, or subconcussive effects (e.g., repetitive head impacts from boxing or soccer without formal concussion diagnosis). This wide range of contexts encompasses the range of typical concussion-related cognitive testing applications.
4. Articles were excluded if individuals were only diagnosed with moderate, severe, or moderate-to-severe traumatic brain injuries.

After applying inclusion criteria, 1254 articles remained of which 1253 full texts were available. The same inclusion criteria were applied to the available full texts. Additionally, articles were excluded if, in the presence of traumatic brain injury, there was not a clearly defined mTBI- or concussion-context group (e.g., articles were excluded when the sample included brain-injured individuals with varying degrees of severity not separated into distinct groups). 768 articles met the inclusion guidelines (Figure 1).

Data were extracted for each included article by two independent coders and included 1) tests used, 2) whether or not the authors reported racial, ethnic, country of origin, or 3) primary language distribution for the participants, and 4) whether or not racial, cultural/ethnic, country of origin, or linguistic characteristics were considered in the analyses, and 5) the reported number of individuals identifying with various racial, ethnic, or linguistic groups. Race and culture/ethnicity were defined as any explicit indication of racial or cultural/ethnic background. Primary language was defined as any explicit indication of the languages spoken by the participants. Country of recruitment was not taken as an implicit identification of race, culture/ethnicity, country of origin, nor language (e.g., participants recruited in South Korea were not assumed to be or to speak South Korean). Due to the varied ways that authors reported race and cultural/ethnic distributions, these two categories are combined into a single category. For example, African-American was reported as “race” in Macciochi et al57 and “ethnicity” in Cole et al.58

**Results**

**Article characteristics**

768 articles published between January 1976 and March 2016 were identified met the inclusion criteria. The majority (n = 489, 63.67%) were published by researchers or groups recruiting participants in the United States (Figure 2).

**Reporting demographics**

Demographic variables of interest were reported in 36.07% (n = 277 articles) of the included articles. Race, culture, ethnicity, or country of origin were reported in 20.01% (n = 164 articles, eTable 1). Participants’ preferred or spoken language was reported in 21.88% (n = 168 articles; eTable 2). Furthermore, 55 of the 277 articles (19.86%; 7.16% of all included articles) reported both language and race, culture/ethnicity, or country of origin. Finally, 14 articles (5.05%; 1.82% of all included articles) included presented stratified outcomes or included these demographic characteristics in the data analyses.42,55–57,59–68

**Articles reporting race, culture, ethnicity, or country of origin.**

Of the 164 articles reporting demographic distributions related to race, culture, ethnicity, or country of origin, 150 reported participants in terms related to race, culture, or ethnicity and six reported participants in terms of their country of origin, with four articles reporting participants in terms of both race, culture or ethnicity and country of origin. Two articles referred to the majority of the participants being Caucasian or White without reporting actual values,69,70 while one simply noted “comparable… ethnic backgrounds” between groups.71 One further article reported individuals in terms of race, culture, or ethnicity, however it was unclear whether the distribution reflected the entire sample including control participants, the entire sample prior to applying exclusionary criteria, or only those individuals with mTBI.72 Therefore, these four studies are not included in subsequent descriptions (*n* = 160 articles).

Among articles reporting race, culture, or ethnicity demographics, 73 descriptors are used, many of which overlap but are applied inconsistently. For example, seven descriptors are applied to individuals traditionally described as “White,” including: White, Caucasian, Caucasian/White, White (non-Hispanic), White or European-American, White (non-Latino), and White Latino (Table 1). Of the 10 articles reporting country of origin, 24 different descriptors are used (Table 2).

Across studies reporting race or ethnicity demographics, “White” (n = 26037, 35.00%) or “Caucasian” (n = 8816, 11.85%) accounted for 46.53% of all participants, with “Hispanic” (n = 12903, 17.34%) and African-American (n = 3772, 5.07%) accounting for the next largest proportions (Table 1). Furthermore individuals identified as “White” or “Caucasian” were the majority of the participants (>50%) in 106 of the 160 articles (Table 1).Participants specifically identified as being from the United States were the majority of all participants across the 10 articles reporting country of origin (n = 31793, 92.04%; Table 2).

Authors made direct comparisons between racial/ethnic groups in six of the 160 articles. These articles present mixed results. No cognitive differences were observed between White, English-speaking South African rugby players and English-speaking American football players56 or between multiple groups (Caucasian, African American, Other).62 Furthermore, while White individuals were more likely to report amnesia than individuals identified as “other”, there were no differences between amnesia and non-amnesia groups on ImPACT subscales.67

By contrast, concussed African Americans exhibited lower visual motor processing speed as well as a greater likelihood to demonstrate at least one cognitive impairment on ImPACT at seven days post-injury.42 Additionally, boxers had a significant decrease in processing speed with increasing fight exposure, used as a proxy for concussion risk, after adjusting for age, race, and education.60 Furthermore, non-European New Zealanders tended to perform less well on CNS Vital Signs at 12-months post injury than European New Zealanders.59 However, the authors are careful to note that there is some evidence of poorer neuropsychological test performance by New Zealanders in comparison to European New Zealanders on traditional neuropsychological testing and therefore cultural bias, rather than true differences in test outcomes, may partially explain these outcomes.

Lower ImPACT test-retest reliability for American college students compared to Irish students was reported in one article.68 However, the groups did not complete the second and third administrations on the same time scale. The Irish students completed tests on days seven and fourteen from baseline whereas the US students completed them on days 45 and 50.68 While these timeframes inform about the long-term stability of the test, the dissimilarity does not permit cross-cultural comparison.

**Articles reporting language.**

Twenty-seven language descriptors were reported over the 168 language-reporting articles. One article specified that most participants spoke French without giving an exact breakdown69 and is not included in subsequent descriptions. A total of 88.62% (n = 148) identified a single language for all participants (see Table 3), with English as the most common language (n = 122). English-monolinguals were represented in 80.24% (n = 134 articles) of these articles, with French-speaking participants being the next most common group (*n* = 8 articles). Additionally, English-monolinguals represented the majority of the participants (> 50%) in 79.04% (n = 132) of these articles. Furthermore, English-monolinguals accounted for 83.50% (n = 79714) of all participants across the 167 articles.

Fourteen articles reported participants from two or more language groups. However, only four articles provided comparisons between multiple language groups. These articles identified clear differences on neurocognitive test performance between language groups. Spanish-English bilinguals demonstrated lower performance on ImPACT, when taking the test in their preferred language (either English or Spanish), than monolingual English-speaking individuals.55,61,64 Additionally, bilinguals taking the test in English performed better than those taking it in Spanish. Furthermore varying test-retest reliability within language groups (English, French, Czech, and Swedish) on ImPACT composite scores at baseline and a one-year follow up were observed.63 However, no between-group comparisons were made to determine whether there were systematic differences.

**Summary**

Concussion is a public health crisis. Objective, quantifiable measures of impairment and recovery are essential not only to diagnosing the individual but documenting recovery and making return-to-learn, -play, and -work decisions as well as tracking function over time. Among the many documented effects of concussion, impairments in memory, executive function, emotional control, decision-making, concentration and attention, and reaction time are frequently observed. Given global patterns of immigration and the subsequent increase in cultural and linguistic diversity in destination countries, such as the United States,23 there is the reasonable necessity for measures that are sensitive to these neurocognitive deficits while accounting for racial, cultural/ethnic, and linguistic characteristics of the participant or patient.

Despite such diversity, fewer than 40% of the articles identified in this review reported participant characteristics with respect to race, culture/ethnicity, or language. Of these articles, White or English-speaking participants are the majority of, or only, participants in approximately 80%. Furthermore, only 2% of the articles accounted for these demographics in the data analyses. Consequently, the external generalizability of the results of the majority of the articles identified here is limited. Furthermore, the effects of concussion on neurocognitive test outcomes in diverse populations is unclear.

Interpreting neurocognitive test results, particularly ImPACT, for individuals from non-White, non-English speaking populations merits caution. Specifically, Spanish-English bilinguals demonstrate lower performance regardless of test language (Spanish or English) than their English-only counterparts. However, taking the test in English consistently yields higher scores.55,61,64 This is true even when bilingual individuals take the test in their preferred language.55 The mechanisms for such differences remain unclear, though education, acculturation, cultural bias, and test translation are all plausible explanations.13,17,22,55,61,64

Furthermore, ImPACT term test-retest reliability for various cultural and linguistic groups may vary as well based on different within-group intraclass correlation coefficients.63,68 However, no between-group studies have fully explored this. Finally, there is evidence of increased symptom-reporting56 and increased likelihood of cognitive impairment42 in non-American and non-White samples, respectively.

The lack of reporting of race, culture/ethnicity, and languages spoken by the participants is problematic in three ways. First, it does not permit the reader to gauge the representativeness of the samples drawn. Second, it does not permit the reader to judge the populations on whom the results are valid and generalizable. Third, it does not allow for testing and evaluating outcomes for differences across racial, cultural/ethnic, and linguistic populations.

**Recommendations for Research**

In light of these findings, two recommendations for future research emerge. First, researchers should begin to obtain and document the race, culture/ethnicity, and language (primary, bilingual status) of participants. Doing so will allow for better external generalizability and facilitate comparisons between articles. Furthermore, reporting these demographic variables may enable researchers to identify correlates and etiology of performance differences on neurocognitive tests when participant outcomes are not homogenous or conflict with reported normative data. Additionally, researchers should endeavor to recruit country-specific representative samples, given global immigration trends.23 This will help ensure greater applicability of the findings to the general population.

Second, future research should investigate differences in neurocognitive outcomes of various populations with respect to concussion. There is limited yet emerging evidence, for differences between English-speaking White Americans and those from other backgrounds.55,64 It is necessary to more fully explain these differences to determine whether there are in fact systematic differences between various groups. Doing so will allow for the development of racially-, culturally/ethnically-, and linguistically-sensitive interpretations.

**Recommendations for Practice**

Cross-cultural neurocognitive testing with tests validated for White, English-speaking individuals introduces issues of cultural bias and misdiagnosis, even in healthy populations.11,15,16,20,73 In light of these concerns42,55,56,61,64 and findings here, clinical interpretation of neurocognitive outcomes with respect to concussion merits caution with diverse populations, particularly when not administered or interpreted by a trained neuropsychologist. Concussion remains a multi-faceted clinical diagnosis, with neurocognitive testing as only one component. It is important to recognize that neurocognitive outcomes at baseline and post-injury may not reflect the true capacity of the individual if the commonly used tests do indeed contain racial, cultural/ethnic, or linguistic biases. Until further research more clearly identifies the role of these demographic variables, no other specific recommendations can be made for the clinician in this area.

**Conclusion**

Current practices for reporting race, culture/ethnicity, and language demographics in concussion-oriented neurocognitive research are inconsistent and insufficient for determining both sample representativeness and generalizability. While some evidence suggests differences between groups, such differences are not fully clarified. Further research and more complete reporting of these demographic variables are required in order to fully evaluate the utility and interpretation of the scores achieved on these tests with diverse populations, particularly when comparing individual performance with normative data. In doing so, both researchers and clinicians can more thoroughly document the magnitude of neurocognitive impairment following concussion and the time-course and trajectory of recovery.

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**References**

1. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil*. 2006;21(5):375-378.

2. McCrea M, Hammeke T, Olsen G, Leo P, Guskiewicz KM. Unreported concussion in high school football players: implications for prevention. *Clin J Sport Med*. 2004;14(1):13–17.

3. Meehan WP, Mannix RC, O’Brien MJ, Collins MW. The prevalence of undiagnosed concussions in athletes. *Clin J Sport Med Off J Can Acad Sport Med*. 2013;23(5):339-342. doi:10.1097/JSM.0b013e318291d3b3.

4. Zuckerman SL, Kerr ZY, Yengo-Kahn A, Wasserman E, Covassin T, Solomon GS. Epidemiology of sports-related concussion in NCAA athletes from 2009-2010 to 2013-2014 incidence, recurrence, and mechanisms. *Am J Sports Med*. 2015;43(11):2654-2662. doi:10.1177/0363546515599634.

5. Hoge CW, McGurk D, Thomas JL, Cox AL, Engel CC, Castro CA. Mild traumatic brain injury in US soldiers returning from Iraq. *N Engl J Med*. 2008;358(5):453–463. doi:10.1056/NEJMoa072972.

6. Cassidy JD, Carroll LJ, Peloso PM, et al. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med*. 2004;(43 Suppl):28-60.

7. Faul M, Xu L, Wald MM, Coronado VG. *Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths 2002-2006*. Atlanta (GA): Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2010. http://origin.glb.cdc.gov/traumaticbraininjury/pdf/blue\_book.docx. Accessed April 25, 2015.

8. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: The 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med*. 2013;47(5):1-12. doi:10.1136/bjsports-2013-092313.

9. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. *Br J Sports Med*. 2017;51:838-847. doi:10.1136/bjsports-2017-097699.

10. Manly JJ, Jacobs DM, Ferraro FR. Future directions in neuropsychological assessment with African Americans. *Minor Cross-Cult Asp Neuropsychol Assess*. 2002:79–96.

11. Manly JJ. Critical issues in cultural neuropsychology: profit from diversity. *Neuropsychol Rev*. 2008;18(3):179-183. doi:10.1007/s11065-008-9068-8.

12. Ardila A. Directions of research in cross-cultural neuropsychology. *J Clin Exp Neuropsychol*. 1995;17(1):143–150.

13. Ardila A. Cultural values underlying psychometric cognitive testing. *Neuropsychol Rev*. 2005;15(4):185–195.

14. Brickman AM, Cabo R, Manly JJ. Ethical issues in cross-cultural neuropsychology. *Appl Neuropsychol*. 2006;13(2):91-100. doi:10.1207/s15324826an1302\_4.

15. Fernández AL, Abe J. Bias in cross-cultural neuropsychological testing: problems and possible solutions. *Cult Brain*. May 2017:1-35. doi:10.1007/s40167-017-0050-2.

16. Puente AE, Perez-Garcia M, Vilar-Lopez R, Hidalgo-Ruzzante N, Fasfous AF. Neuropsychological assessment of culturally and educationally dissimilar individuals. *Handb Multicult Ment Health Assess Treat Diverse Popul*. 2013:225–241.

17. Jacobs DM, Sano M, Albert S, Schofield P, Dooneief G, Stern Y. Cross-cultural neuropsychological assessment: A comparison of randomly selected, demographically matched cohorts of English-and Spanish-speaking older adults. *J Clin Exp Neuropsychol*. 1997;19(3):331-339. doi:10.1080/01688639708403862.

18. Norman MA, Evans JD, Miller WS, Heaton RK. Demographically corrected norms for the California Verbal Learning Test. *J Clin Exp Neuropsychol*. 2000;22(1):80-94. doi:10.1076/1380-3395(200002)22:1;1-8;FT080.

19. Norman MA, Moore DJ, Taylor M, et al. Demographically corrected norms for African Americans and Caucasians on the Hopkins Verbal Learning Test–Revised, Brief Visuospatial Memory Test–Revised, Stroop Color and Word Test, and Wisconsin Card Sorting Test 64-Card Version. *J Clin Exp Neuropsychol*. 2011;33(7):793-804. doi:10.1080/13803395.2011.559157.

20. Daugherty JC, Puente AE, Fasfous AF, Hidalgo-Ruzzante N, Pérez-Garcia M. Diagnostic mistakes of culturally diverse individuals when using North American neuropsychological tests. *Appl Neuropsychol Adult*. 2017;24(1):16–22.

21. Candelaria MA, Llorente AM. The assessment of the Hispanic child. In: *Handbook of Clinical Child Neuropsychology*. Springer; 2009:401–424. http://link.springer.com/chapter/10.1007/978-0-387-78867-8\_18.

22. Echemendia RJ, Harris JG, Congett SM, Diaz ML, Puente AE. Neuropsychological training and practices with Hispanics: A national survey. *Clin Neuropsychol*. 1997;11(3):229-243. doi:10.1080/13854049708400451.

23. The International Organization for Migration. 2015 Global Migration Trends Factsheet. 2017. http://gmdac.iom.int/global-migration-trends-factsheet.

24. Giza CC, Kutcher JS, Ashwal S, et al. Summary of evidence-based guideline update: Evaluation and management of concussion in sports: Report of the Guideline Development Subcommittee of the American Academy of Neurology. *Neurology*. 2013;80(24):2250-2257. doi:10.1212/WNL.0b013e31828d57dd.

25. Jha N, Cantu R, Gennarelli TA, et al. International concussion consensus 2015. *Curr Res Concussion*. 2015;2(3):68-80.

26. Lovell MR, Iverson GL, Collins MW, et al. Measurement of symptoms following sports-related concussion: reliability and normative data for the post-concussion scale. *Appl Neuropsychol*. 2006;13(3):166–174.

27. Meehan WP, Mannix R, Monuteaux MC, Stein CJ, Bachur RG. Early symptom burden predicts recovery after sport-related concussion. *Neurology*. 2014;83(24):2204-2210. doi:10.1212/WNL.0000000000001073.

28. McCrory P. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med*. 2005;39(Supplement 1):i78-i86. doi:10.1136/bjsm.2005.018614.

29. Harmon KG, Drezner JA, Gammons M, et al. American Medical Society for Sports Medicine position statement: concussion in sport. *Br J Sports Med*. 2013;47(1):15-26. doi:10.1136/bjsports-2012-091941.

30. McCrea MA, Nelson LD, Guskiewicz K. Diagnosis and Management of Acute Concussion. *Phys Med Rehabil Clin N Am*. 2017;28(2):271-286. doi:10.1016/j.pmr.2016.12.005.

31. Broglio SP, Puetz TW. The effect of sport concussion on neurocognitive function, self-report symptoms and postural control. *Sports Med*. 2008;38(1):53–67.

32. Collins MW, Grindel SH, Lovell MR, et al. Relationship between concussion and neuropsychological performance in college football players. *JAMA J Am Med Assoc*. 1999;282(10):964-970. doi:10.1001/jama.282.10.964.

33. Collins MW, Iverson GL, Lovell MR, McKeag DB, Norwig J, Maroon J. On-field predictors of neuropsychological and symptom deficit following sports-related concussion. *Clin J Sport Med*. 2003;13(4):222–229.

34. Covassin T, Elbin RJ, Harris W, Parker T, Kontos AP. The role of age and sex in symptoms, neurocognitive performance, and postural stability in athletes after concussion. *Am J Sports Med*. 2012;40(6):1303-1312. doi:10.1177/0363546512444554.

35. Guskiewicz KM. Balance assessment in the management of sport-related concussion. *Clin Sports Med*. 2011;30(1):89–102.

36. Peterson CL, Ferrara MS, Mrazik M, Piland S, Elliott R. Evaluation of neuropsychological domain scores and postural stability following cerebral concussion in sports. *Clin J Sport Med*. 2003;13(4):230–237.

37. Schatz P, Pardini JE, Lovell MR, Collins MW, Podell K. Sensitivity and specificity of the ImPACT test battery for concussion in athletes. *Arch Clin Neuropsychol*. 2006;21(1):91-99. doi:10.1016/j.acn.2005.08.001.

38. Valovich McLeod TC, Barr WB, McCrea M, Guskiewicz KM. Psychometric and measurement properties of concussion assessment tools in youth sports. *J Athl Train*. 2006;41(4):399-408.

39. Sady MD, Vaughan CG, Gioia GA. Psychometric characteristics of the Postconcussion Symptom Inventory in children and adolescents. *Arch Clin Neuropsychol*. 2014;29(4):348-363. doi:10.1093/arclin/acu014.

40. Barr WB, McCrea M. Sensitivity and specificity of standardized neurocognitive testing immediately following sports concussion. *J Int Neuropsychol Soc*. 2001;7(6):693-702.

41. Schatz P, Sandel N. Sensitivity and specificity of the online version of ImPACT in high school and collegiate athletes. *Am J Sports Med*. 2013;41(2):321-326. doi:10.1177/0363546512466038.

42. Kontos AP, Elbin RJ, Covassin T, Larson E. Exploring differences in computerized neurocognitive concussion testing between African American and White athletes. *Arch Clin Neuropsychol*. 2010;25(8):734-744.

43. McCrea M, Kelly JP, Randolph C, et al. Standardized Assessment of Concussion (SAC): on-site mental status evaluation of the athlete. *J Head Trauma Rehabil*. 1998;13(2):27-35.

44. Collie A, Maruff P, Makdissi M, McCrory P, McStephen M, Darby D. CogSport: reliability and correlation with conventional cognitive tests used in postconcussion medical evaluations. *Clin J Sport Med*. 2003;13(1):28-32.

45. McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following concussion in collegiate football players: The NCAA Concussion Study. *JAMA J Am Med Assoc*. 2003;290(19):2556-2563.

46. McCrea M, Kelly JP, Randolph C, Cisler R, Berger L. Immediate neurocognitive effects of concussion. *Neurosurgery*. 2002;50(5):1032–1042.

47. Maroon JC, Lovell MR, Norwig J, Podell K, Powell JW, Hartl R. Cerebral concussion in athletes: Evaluation and neuropsychological testing. *Neurosurgery*. 2000;47(3):659–672.

48. Belanger HG, Vanderploeg RD. The neuropsychological impact of sports-related concussion: a meta-analysis. *J Int Neuropsychol Soc*. 2005;11(04):345–357.

49. Schneider KJ, Iverson GL, Emery CA, McCrory P, Herring SA, Meeuwisse WH. The effects of rest and treatment following sport-related concussion: a systematic review of the literature. *Br J Sports Med*. 2013;47(5):304-307. doi:10.1136/bjsports-2013-092190.

50. Chen J-K, Johnston KM, Frey S, Petrides M, Worsley K, Ptito A. Functional abnormalities in symptomatic concussed athletes: an fMRI study. *NeuroImage*. 2004;22(1):68-82. doi:10.1016/j.neuroimage.2003.12.032.

51. Gosselin N, Bottari C, Chen J-K, et al. Electrophysiology and functional MRI in post-acute mild traumatic brain injury. *J Neurotrauma*. 2011;28(3):329-341. doi:10.1089/neu.2010.1493.

52. McAllister TW, Sparling MB, Flashman LA, Guerin SJ, Mamourian AC, Saykin AJ. Differential working memory load effects after mild traumatic brain injury. *NeuroImage*. 2001;14(5):1004–1012. doi:10.1006/nimg.2001.0899.

53. Tsushima WT, Siu AM. Neuropsychological test performance of Hawai’i high school athletes: updated Hawai’i immediate post-concussion assessment and cognitive testing data. *Hawaii J Med Public Health*. 2014;73(7):208-211.

54. Tsushima WT, Oshiro R, Zimbra D. Neuropsychological test performance of Hawai’i high school athletes: Hawai’i ImPACT normative data. *Hawaii Med J*. 2008;67(4):93-95.

55. Ott S, Schatz P, Solomon G, Ryan JJ. Neurocognitive performance and symptom profiles of Spanish-speaking Hispanic athletes on the ImPACT Test. *Arch Clin Neuropsychol*. 2014;29(2):152-163. doi:10.1093/arclin/act091.

56. Shuttleworth-Edwards AB, Whitefield-Alexander VJ, Radloff SE, Taylor AM, Lovell MR. Computerized neuropsychological profiles of South African versus US athletes: a basis for commentary on cross-cultural norming issues in the sports concussion arena. *Phys Sportsmed*. 2009;37(4):45-52. doi:10.3810/psm.2009.12.1741.

57. Macciocchi SN, Seel RT, Thompson N. The impact of mild traumatic brain injury on cognitive functioning following co-occurring spinal cord injury. *Arch Clin Neuropsychol*. 2013;28(7):684-691.

58. Cole WR, Arrieux JP, Schwab K, Ivins BJ, Qashu FM, Lewis SC. Test–retest reliability of four computerized neurocognitive assessment tools in an active duty military population. *Arch Clin Neuropsychol*. 2013;28(7):732-742.

59. Barker-Collo S, Jones K, Theadom A, et al. Neuropsychological outcome and its correlates in the first year after adult mild traumatic brain injury: A population-based New Zealand study. *Brain Inj*. 2015;29(13-14):1604-1616. doi:10.3109/02699052.2015.1075143.

60. Bernick C, Banks SJ, Shin W, et al. Repeated head trauma is associated with smaller thalamic volumes and slower processing speed: the Professional Fighters’ Brain Health Study. *Br J Sports Med*. 2015;49(15):1007-1011. doi:10.1136/bjsports-2014-093877.

61. Blake ML, Ott S, Villanyi E, Kazhuro K, Schatz P. Influence of language of administration on ImPACT performance by bilingual Spanish–English college students. *Arch Clin Neuropsychol*. 2015;30(4):302-309. doi:10.1093/arclin/acv021.

62. Broshek DK, Kaushik T, Freeman JR, Erlanger D, Webbe F, Barth JT. Sex differences in outcome following sports-related concussion. *J Neurosurg*. 2005;102(5):856–863.

63. Bruce JM, Echemendia R, Meeuwisse W, Comper P, Sisco A. 1 year test–retest reliability of ImPACT in professional ice hockey players. *Clin Neuropsychol*. 2014;28(1):14-25. doi:10.1080/13854046.2013.866272.

64. Jones NS, Walter KD, Caplinger R, Wright D, Raasch WG, Young C. Effect of education and language on baseline concussion screening tests in professional baseball players. *Clin J Sport Med*. 2014;24(4):284-288. doi:10.1097/JSM.0000000000000031.

65. Larson EB, Kondiles BR, Starr CR, Zollman FS. Postconcussive complaints, cognition, symptom attribution and effort among veterans. *J Int Neuropsychol Soc*. 2013;19(1):88-95. doi:10.1017/S1355617712000999.

66. Rabinowitz AR, Li X, McCauley SR, et al. Prevalence and predictors of poor recovery from mild traumatic brain injury. *J Neurotrauma*. 2015;32(19):1488-1496. doi:10.1089/neu.2014.3555.

67. Register-Mihalik JK, De Maio VJ, Tibbo-Valeriote HL, Wooten JD. Characteristics of pediatric and adolescent concussion clinic patients with postconcussion amnesia. *Clin J Sport Med*. 2015;25(6):502-508. doi:10.1097/JSM.0000000000000161.

68. Resch JE, Driscoll A, McCaffrey N, et al. ImPact test-retest reliability: Reliably unreliable? *J Athl Train*. 2013;48(4):506-511. doi:10.4085/1062-6050-48.3.09.

69. Pineau H, Marchand A, Guay S. Objective neuropsychological deficits in post-traumatic stress disorder and mild traumatic brain injury: What remains beyond symptom similarity? *Behav Sci*. 2014;4(4):471-486. doi:10.3390/bs4040471.

70. Shuttleworth-Edwards AB, Radloff SE. Compromised visuomotor processing speed in players of Rugby Union from school through to the national adult level. *Arch Clin Neuropsychol*. 2008;23(5):511-520. doi:10.1016/j.acn.2008.05.002.

71. Meyer JE, Arnett PA. Changes in symptoms in concussed and non-concussed athletes following neuropsychological assessment. *Dev Neuropsychol*. 2015;40(1):24-28. doi:10.1080/87565641.2014.1001065.

72. Levin HS, Mattis S, Ruff RM, et al. Neurobehavioral outcome following minor head injury: a three-center study. *J Neurosurg*. 1987;66(2):234–243.

73. Olson K, Jacobson K. Cross-cultural considerations in pediatric neuropsychology: A review and call to attention. *Appl Neuropsychol Child*. 2015;4(3):166-177. doi:10.1080/21622965.2013.830258.

| **Table 1. Breakdown of participants by race and ethnicity descriptors across articles reporting such descriptors (*n* = 154)** | | | | |
| --- | --- | --- | --- | --- |
| **Race or ethnicity descriptor** | **Total number of participants** | **Proportion of all participants (%)** | **# of studies reporting** | **# of studies with majority (>50%)** |
| White | 26037 | 34.995 | 40 | 36 |
| Hispanic | 12903 | 17.342 | 34 | 1 |
| Caucasian | 8816 | 11.849 | 78 | 70 |
| African-American | 3772 | 5.07 | 66 | 3 |
| South African | 1869 | 2.512 | 3 | 1 |
| Black | 1201 | 1.614 | 19 | 1 |
| Other | 581 | 0.781 | 45 |  |
| New Zealand European | 533 | 0.716 | 4 | 4 |
| Caucasian/White | 415 | 0.558 | 2 | 2 |
| Maori | 333 | 0.448 | 5 |  |
| Ethnic Minority | 326 | 0.438 | 1 |  |
| European American | 324 | 0.435 | 3 | 1 |
| Norweigan or Scandinavian | 317 | 0.426 | 1 | 1 |
| Non-Hispanic | 301 | 0.405 | 2 | 2 |
| Finnish | 264 | 0.355 | 1 | 1 |
| Black or African American | 242 | 0.325 | 3 | 1 |
| English or European | 242 | 0.325 | 1 |  |
| Dutch | 228 | 0.306 | 3 | 3 |
| White (non-Hispanic) | 199 | 0.267 | 2 | 1 |
| Minority | 188 | 0.253 | 2 |  |
| Asian | 182 | 0.245 | 24 |  |
| Non-Black | 145 | 0.195 | 2 | 2 |
| Mixed racial background | 112 | 0.151 | 3 |  |
| Unknown | 108 | 0.145 | 4 |  |
| Hispanic or Latino | 104 | 0.14 | 9 |  |
| Native Hawaiian or Pacific Islander | 99 | 0.133 | 4 |  |
| Latino | 91 | 0.122 | 5 |  |
| White or European American | 90 | 0.121 | 1 |  |
| Pacific Islander | 68 | 0.091 | 5 |  |
| Asian American | 64 | 0.086 | 11 |  |
| Australian | 64 | 0.086 | 2 | 2 |
| Chinese | 63 | 0.085 | 2 | 1 |
| Hispanic American | 50 | 0.067 | 3 |  |
| Irish | 46 | 0.062 | 1 | 1 |
| White (non-Latino) | 35 | 0.047 | 1 | 1 |
| Polynesian Malay | 31 | 0.042 | 1 | 1 |
| Other European | 26 | 0.035 | 2 |  |
| Mixed ethnicities | 23 | 0.031 | 2 |  |
| Indigenous | 22 | 0.03 | 1 |  |
| Other/Unknown | 21 | 0.028 | 1 |  |
| Biracial or multiracial | 20 | 0.027 | 2 |  |
| Scandinavian | 19 | 0.026 | 1 |  |
| Unreported | 19 | 0.026 | 2 |  |
| Indian | 16 | 0.022 | 2 |  |
| Malay | 16 | 0.022 | 2 | 1 |
| Native American | 16 | 0.022 | 8 |  |
| Polynesian American | 16 | 0.022 | 1 |  |
| Mixed or multiple | 14 | 0.019 | 2 |  |
| Multiracial | 12 | 0.016 | 3 |  |
| Asian, East Indian, Other Asian | 10 | 0.013 | 1 |  |
| Pacific | 9 | 0.012 | 1 |  |
| Asian Indian | 8 | 0.011 | 1 |  |
| Filipino | 8 | 0.011 | 1 |  |
| Aboriginal | 7 | 0.009 | 1 |  |
| Multicultural | 7 | 0.009 | 1 |  |
| Non-Caucasian | 7 | 0.009 | 1 |  |
| African American, Asian, or Other | 6 | 0.008 | 1 |  |
| East Indian | 6 | 0.008 | 1 |  |
| African-American/Black | 5 | 0.007 | 1 |  |
| African or Caribbean | 4 | 0.005 | 1 |  |
| American Indian | 4 | 0.005 | 3 |  |
| Asian or Pacific Islander | 4 | 0.005 | 3 |  |
| Biracial | 4 | 0.005 | 2 |  |
| Zimbabwean | 4 | 0.005 | 1 |  |
| Latin American | 3 | 0.004 | 2 |  |
| First Nations | 2 | 0.003 | 1 |  |
| Multi-ethnic | 2 | 0.003 | 1 |  |
| Undeclared ethnicity | 2 | 0.003 | 1 |  |
| Unspecified | 2 | 0.003 | 1 |  |
| White Latino | 2 | 0.003 | 1 |  |
| American Indian or Alaskan Native | 1 | 0.001 | 1 |  |
| Missing | 1 | 0.001 | 1 |  |
| Native American or Alaskan Native | 1 | 0.001 | 1 |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 2. Breakdown of participants by country of origin descriptors across articles reporting such descriptors (*n* = 10)** | | | | |
| **Country of Origin** | **Total number of participants** | **Proportion of all participants (%)** | **# of studies reporting** | **# of studies with majority (>50%)** |
| United States | 31793 | 92.042 | 3 | 3 |
| US - English as primary language | 275 | 0.796 | 1 | 1 |
| Norway | 193 | 0.559 | 1 | 1 |
| Australia or New Zealand | 183 | 0.53 | 1 | 1 |
| US or Canada | 86 | 0.249 | 2 | 1 |
| Spain | 61 | 0.177 | 1 | 1 |
| Dominican Republic | 60 | 0.174 | 1 |  |
| Netherlands | 60 | 0.174 | 1 | 1 |
| Mexico | 18 | 0.052 | 2 |  |
| Venezuela | 18 | 0.052 | 1 |  |
| Canada | 16 | 0.046 | 1 |  |
| US - Spanish as primary language | 13 | 0.038 | 1 |  |
| United Kingdom | 10 | 0.029 | 1 |  |
| India | 7 | 0.02 | 1 |  |
| South America | 5 | 0.014 | 1 |  |
| Puerto Rico | 3 | 0.009 | 1 |  |
| Cuba | 2 | 0.006 | 1 |  |
| Brazil | 1 | 0.003 | 1 |  |
| Egypt | 1 | 0.003 | 1 |  |
| Indonesia | 1 | 0.003 | 1 |  |
| Lebanon | 1 | 0.003 | 1 |  |
| Nicaragua | 1 | 0.003 | 1 |  |
| Singapore | 1 | 0.003 | 1 |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 3. Breakdown of participants by language descriptors across articles reporting such descriptors (*n* = 168)** | | | | | |
| **Language** | **Total number of participants** | **Proportion of all participants (%)** | **# of studies reporting** | **# of studies with majority** | **# of monolingual studies** |
| English | 79733 | 83.503 | 134 | 132 | 122 |
| Spanish-English Bilingual | 11856 | 12.417 | 2 |  |  |
| French | 777 | 0.814 | 8 | 7 | 7 |
| Finnish | 523 | 0.548 | 5 | 4 | 3 |
| Spanish | 317 | 0.332 | 5 | 1 | 1 |
| English or Spanish | 245 | 0.257 | 3 | 3 | 3 |
| English or Afrikaans | 226 | 0.237 | 1 | 1 | 1 |
| German | 217 | 0.227 | 5 | 4 | 3 |
| Swedish | 181 | 0.19 | 3 | 2 | 1 |
| Greek | 102 | 0.107 | 2 | 2 | 2 |
| English as first language | 81 | 0.085 | 2 | 2 |  |
| English or French | 80 | 0.084 | 2 | 2 | 2 |
| English as a second language | 79 | 0.083 | 2 |  |  |
| Czech | 45 | 0.047 | 1 |  |  |
| English Bilingual (any second language) | 41 | 0.043 | 2 |  |  |
| Dutch | 40 | 0.042 | 1 | 1 | 1 |
| Spanish Preferred | 38 | 0.04 | 1 | 1 |  |
| Russian | 24 | 0.025 | 1 |  |  |
| Italian | 23 | 0.024 | 1 | 1 | 1 |
| Mandarin | 22 | 0.023 | 1 |  |  |
| English or Malay | 21 | 0.022 | 1 | 1 | 1 |
| Non-English and non-Finnish | 19 | 0.02 | 1 |  |  |
| English Preferred | 16 | 0.017 | 1 |  |  |
| Non-English | 9 | 0.009 | 1 |  |  |
| English or Spanish Preferred | 6 | 0.006 | 1 |  |  |
| Other | 3 | 0.003 | 1 |  |  |
| English-Swedish Bilingual | 1 | 0.001 | 1 |  |  |

**Figure captions**

**Figure 1.** Study selection PRISMA flowsheet

**Figure 2.** Number of articles by country. Colors are present in a log10 scale. For reference, research groups in the United States contributed 489 articles.