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Preseason Baseline Neurocognitive Performances and Symptom Reporting on Immediate Post-Concussion Assessment and Cognitive Testing: A Comparison of Adolescent Student-Athletes Tested in Spanish and English

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Context: Student-athletes are commonly administered the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery at preseason baseline and postconcussion. The ImPACT is available in many languages, but few researchers have examined differences in cognitive performances and symptom ratings based on the language of administration.

Objective: To examine differences in ImPACT neurocognitive composites and symptom reporting at preseason baseline testing between student-athletes who completed ImPACT in Spanish versus English.

Design: Cross-sectional study.

Setting: Preseason baseline testing for a high school concussion-management program in Maine.

Patients or Other Participants: Adolescent student-athletes who completed testing in Spanish (n = 169) and English (n = 169) were matched on age, gender, and health and academic history. Language groups were compared on each outcome for the full sample and for gender-stratified subsamples.

Main Outcome Measure(s): Neurocognitive composite scores and individual and total symptom severity ratings from the ImPACT battery.

Results: Athletes tested in Spanish displayed lower levels of neurocognitive performance on 2 of 5 composite scores (visual motor speed: $P < .001$, d = 0.51; reaction time: $P = .004$, d = 0.33) and reported greater symptom severity ($P < .001$, $r = 0.21$). When the analyses were stratified by gender, similar visual motor speed differences were observed between language groups among boys ($P = .001$, d = 0.49) and girls ($P = .001$, d = 0.49), whereas reaction time showed a larger group difference for boys ($P = .012$, d = 0.42) than for girls ($P = .128$, d = 0.21). Language-group differences in symptom reporting were similar for boys ($P = .003$, $r = 0.22$) and girls ($P = .008$, $r = 0.21$), with more frequent endorsement of physical and affective symptoms by athletes tested in Spanish.

Conclusions: Language-group differences in total symptom severity were small ($r = 0.21$) and in neurocognitive performances were small to medium ($d = 0.05$–0.51). Versus previous authors who compared athletes tested in Spanish and English with ImPACT, we observed smaller effects, which may be attributable to close matching on variables related to neurocognitive performances and symptom reporting.

Key Words: cross-cultural comparison, neuropsychology, sports, concussion, postconcussion syndrome

Key Points

- Adolescent student-athletes who completed baseline preseason Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) in Spanish displayed lower levels of performance in the visual motor speed and reaction time composite scores than those tested in English.
- When interpreting ImPACT scores, clinicians should be mindful that some neurocognitive performances may be, on average, lower than expected among student-athletes tested in Spanish compared with English-language norms.
- During baseline preseason ImPACT assessments, student-athletes tested in Spanish reported greater symptom severity, including more physical and affective symptoms, than those tested in English.

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery is commonly used in preseason baseline assessments of athletes who are at risk of experiencing a sport-related concussion. When interpreting postinjury performances on ImPACT, clinicians must appreciate demographic characteristics and health history variables that may be associated with lower levels of neurocognitive performances or greater symptom reporting before a concussion, including age,[1] gender,[2] race or ethnicity,[3,4] attention-deficit disorder (ADD) or attention-deficit/hyperactivity disorder (ADHD),[5,6] or a history of migraines or mental health problems.[7] Another important consideration is the language of administration, especially when performances are compared against English-language ImPACT normative data. Researchers have begun to evaluate differences in baseline neurocognitive performances and symptom severity between English and Spanish speakers. A study[3] that compared athletes tested in English versus Spanish demonstrated group differences in ImPACT neurocognitive composite scores and symptom reporting; athletes who completed the battery in Spanish performed at a lower level on all composites and reported more baseline symptoms than athletes who completed the battery in English. Research[8] on professional baseball players produced similar results: players who spoke Spanish as their first language performed at a lower level on all neurocognitive composites than players who spoke English as their first language. The reasons for the lower performance levels in athletes tested in Spanish are likely multifaceted and related to such factors as socioeconomic status,[9] acculturative experiences,[10–12] and quality of education.[13,14] Our aim was to add to the body of research examining baseline differences in ImPACT neurocognitive performances and symptom reporting associated with the language of administration, comparing adolescent student-athletes who chose to complete ImPACT in English with those who completed it in Spanish. Because of known gender differences in ImPACT scores at baseline,[1,2,7,15] these comparisons were conducted for all participants and separately for boys and girls. Consistent with previous findings, we hypothesized that lower-level neurocognitive performances and greater symptom reporting would be observed among adolescent athletes who completed ImPACT in Spanish compared with those who completed the battery in English.

METHODS

Participants

Between 2009 and 2015, adolescent student-athletes (N = 47 606, age = 13–18 years) from approximately 100 middle schools and high schools across the state of Maine completed ImPACT as a component of the preseason baseline evaluation. From this larger sample, 182 student-athletes chose to complete ImPACT in Spanish. Participants were excluded if they had invalid test performance (n = 10) or self-reported past treatment for meningitis (n = 2) or seizures (n = 1). No participants reported a history of brain surgery or diagnosis of autism. This resulted in a sample of 169 participants who completed ImPACT in Spanish. A matched comparison group was drawn from student-athletes who completed ImPACT in English with valid test performances and no self-reported history of an autism diagnosis or treatment for seizures, brain surgery, or meningitis (N = 42951). Matching was conducted using case-control matching in SPSS (version 25; IBM Corp), which identified participants tested in English who matched participants tested in Spanish on demographic variables (ie, age, gender), academic history variables (ie, diagnosis of learning disability or dyslexia, history of special education), and health history variables (ie, concussion history, self-reported diagnosis of ADD or ADHD, previous treatment for a psychiatric condition such as depression or anxiety, and previous treatment for a substance use disorder, headaches, or migraines). This case-control matching procedure revealed exact matches tested in English for 167 participants tested in Spanish and 2 close matches that varied in age by ± 2 years. The final sample consisted of 169 participants tested in Spanish (age = 15.82 ± 1.11 years, range = 13–18, 55.0% boys) and 169 participants tested in English (mean = 15.82 ± 1.11 years, range = 13–18; 55.0% boys). Data regarding race and ethnicity were not available.

Procedures

Participants completed a self-report survey of sport affiliation and health and academic history information, including questions on whether they had "been diagnosed with ADD/ADHD" or "had problems with ADD/hyperactivity," been "diagnosed with dyslexia" or been "diagnosed with a learning disability," attended special education classes, or repeated 1 or more years of school. They were also asked about the number of lifetime diagnosed concussions and past treatment for headaches, migraines, epilepsy or seizures, brain surgery, meningitis, substance or alcohol use, or a psychiatric condition (eg, anxiety or depression). All student-athletes completed ImPACT as a preseason baseline in a group setting in high school computer laboratories, administered by the local athletic training staff. Testing data were merged into a statewide data set. Institutional review board approval for use of this deidentified database was obtained from Colby College, and an exemption was obtained from Spaulding Rehabilitation Hospital for secondary use.

Measures

Immediate Post-Concussion Assessment and Cognitive Testing consists of 6 computer-administered neuropsychological test modules and the Post-Concussion Symptom Scale (PCSS). The ImPACT scores used as dependent variables in this study were the 5 neurocognitive composites (ie, verbal memory, visual memory, visual motor speed, reaction time, and impulse control) and the PCSS total symptom score.[16] For verbal memory, visual memory, and visual motor speed, higher scores indicate better performances; and for reaction time and impulse control, lower scores indicate better performances. On the PCSS, a higher score indicates greater symptom severity. We also evaluated the 22 individual PCSS items for group differences in symptom endorsement (ie, rated as 1 or more on a 0–6 scale).

Statistical Analyses

Independent-samples *t* tests were used to compare participants tested in Spanish with participants tested in

Table 1. **Participants' Academic and Health Histories and Sport Affiliations**

Characteristic	Tested in English, No. (%) Total Sample (n = 169)	Boys (n = 93)	Girls (n = 76)	Tested in Spanish, No. (%) Total Sample (n = 169)	Boys (n = 93)	Girls (n = 76)
Academic and health history						
Received speech therapy[a]	4 (2.4)	2 (2.2)	2 (2.6)	9 (5.3)	9 (9.7)	0 (0)
Attended special education classes	1 (1.1)	1 (1.3)		2 (1.2)	1 (1.3)	2 (1.2)
Repeated academic grade[a]	12 (7.1)	9 (9.7)	3 (3.9)	17 (10.1)	13 (14.0)	4 (5.3)
Learning disability/dyslexia	5 (3.0)	4 (4.3)	1 (1.3)	5 (3.0)	4 (4.3)	1 (1.3)
ADD/ADHD	19 (11.2)	15 (16.1)	4 (5.3)	19 (11.2)	15 (16.1)	4 (5.3)
Treatment for headache	25 (16.0)	9 (10.5)	16 (22.9)	25 (16.8)	9 (11.0)	16 (23.9)
Treatment for migraines	13 (8.4)	6 (7.1)	7 (10.0)	13 (10.2)	6 (8.6)	7 (12.3)
Treatment for substance or alcohol use	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Treatment for a psychiatric condition	5 (3.3)	2 (2.4)	3 (4.3)	5 (4.0)	2 (2.9)	3 (5.4)
Sport affiliation						
American football	28 (16.6)	28 (30.1)	0 (0)	5 (3.0)	5 (4.4)	1 (1.3)
Baseball	7 (4.1)	7 (7.5)	0 (0)	0 (0)	0 (0)	0 (0)
Basketball	16 (9.5)	8 (8.6)	8 (10.5)	12 (7.1)	5 (5.4)	7 (9.2)
Cheerleading	8 (4.7)	0 (0)	8 (10.5)	2 (1.2)	0 (0)	2 (2.6)
Field hockey	16 (9.5)	0 (0)	16 (21.1)	8 (4.4)	1 (1.1)	7 (9.2)
Ice hockey	10 (5.9)	9 (9.7)	1 (1.3)	0 (0)	0 (0)	0 (0)
Skiing (alpine)	1 (0.6)	0 (0)	1 (1.3)	8 (4.7)	4 (4.3)	4 (5.3)
Soccer	30 (17.8)	13 (14.0)	17 (22.4)	71 (42.0)	54 (58.1)	17 (22.4)
Softball	8 (4.7)	0 (0)	8 (10.5)	0 (0)	0 (0)	0 (0)
Swimming	5 (3.0)	3 (3.2)	2 (2.6)	5 (3.0)	1 (1.1)	4 (5.3)
Tennis	5 (3.0)	3 (3.2)	2 (2.6)	13 (7.7)	5 (5.4)	8 (10.5)
Track and field	11 (6.5)	7 (7.5)	4 (5.3)	8 (4.7)	2 (2.2)	6 (7.9)
Volleyball	3 (1.8)	0 (0)	3 (3.9)	6 (3.6)	0 (0)	6 (7.9)
Other[b]	21 (12.3)	15 (16.2)	6 (8.0)	31 (18.6)	19 (18.0)	14 (18.4)

Abbreviations: ADD, attention-deficit disorder; ADHD, attention-deficit/hyperactivity disorder.

[a] The numbers do not match exactly across the groups tested in English and Spanish because participants were not matched based on receiving speech therapy or repeating an academic grade.

[b] Other sports include boating related, diving, equestrian, golf, gymnastics, lacrosse, mountain biking, skiing (cross-country), skiing (free ride), skiing (freestyle moguls), skiing (Nordic combined), snowboarding (boardercross), and snowboarding (cross-country).

English on the 5 ImPACT cognitive test composite raw scores and, due to a non-normal distribution, a Mann-Whitney U test was used to compare these groups on the PCSS total symptom score. Significance was set at $P <$ .002 (ie, $\alpha = 0.05/18$) based on a Bonferroni correction to control our familywise type I error rate, planning on 18 pairwise comparisons: 5 ImPACT cognitive composite scores and the PCSS total symptom score were compared between language groups for the full sample and each gender separately. Post hoc analyses compared total symptom severity between boys and girls within each language group.

Effect sizes for parametric comparisons were determined via Cohen d, which was calculated as

$$d = \frac{M_2 - M_1}{\sqrt{\left(\left(SD_1^2 + SD_2^2\right)/2\right)}},$$

and for nonparametric comparisons as r, which was calculated as $r = \frac{Z}{\sqrt{N}}$.[17] Effect sizes were interpreted according to conventional guidelines: d = 0.20 or r = 0.10 were interpreted as *small*, d = 0.50 or r = 0.30 as *medium*, and d = 0.80 or r = 0.50 as *large*.[18] Group differences in individual symptom endorsement rates were examined via odds ratios (ORs), which were interpreted as *small* (OR = 1.20–1.71), *medium* (OR = 1.72–2.40), or *large* (OR > 2.40) based on a conversion method and widely used criteria.[18,19] All ORs were coded so that values >1.00 indicated greater odds of endorsing the symptom by the language group with a higher endorsement rate. Data analyses were conducted using SPSS.

RESULTS

Characteristics of the Student-Athletes

Information regarding participants' academic and health history, including a history of learning disability or dyslexia diagnosis; ADHD diagnosis; special education; repeated academic grade; number of prior concussions; prior treatment for headache, migraine, substance use, or psychiatric conditions; and sport affiliation at the time of baseline testing is provided in Table 1. The student-athletes tested in Spanish were active in many different sports, such as soccer (42.0%), basketball (7.1%), and tennis (7.7%), at the time of baseline assessment. The most common sport affiliations reported by student-athletes tested in English were soccer (17.8%), American football (16.6%), and basketball (9.5%).

Cognitive Test Performance

The language groups differed on 1 of the 5 ImPACT neurocognitive composites. Student-athletes tested in Spanish performed at a lower level on the visual motor speed composite score than those tested in English ($P <$ .001, d = 0.51, medium effect size; Table 2). The participants tested in Spanish were slower in reaction time composite score, and the group difference approached the

Table 2. Summary of Group Differences in ImPACT Composite and Total Symptom Scores

	Tested in Spanish			Tested in English					
ImPACT Component	Median	Mean ± SD	Range	Median	Mean ± SD	Range	*t* and U Values	*P* Value	*d* and *r* Values
Total sample									
Verbal memory	83.00	82.05 ± 11.36	48–100	84.00	83.79 ± 9.51	55–100	*t* = –1.53	.126	d = 0.17
Visual memory	74.00	71.43 ± 13.51	31–96	74.00	73.01 ± 12.89	32–98	*t* = –1.10	.270	d = 0.12
Visual motor speed	32.42	31.97 ± 7.11	12.55–50.00	35.08	35.71 ± 7.45	8.00–53.33	*t* = 4.72	<.001	d = 0.51
Reaction time[a]	0.63	0.65 ± 0.09	0.45–1.07	0.60	0.62 ± 0.09	0.45–1.05	*t* = –2.92	.004	d = 0.33
Impulse control[a]	6	7.02 ± 5.41	0–29	7	7.25 ± 4.60	0–27	*t* = 0.42	.673	d = 0.05
Total symptom score[a]	7	10.97 ± 13.87	0–84	3	5.82 ± 7.61	0–44	U = 10,851.5	<.001	*r* = 0.21
Girls only									
Verbal memory	84.50	83.54 ± 11.04	54–100	85.00	85.11 ± 8.72	59–100	*t* = 0.97	.334	d = 0.16
Visual memory	75.00	75.00 ± 14.49	31–96	75.00	74.51 ± 12.36	32–96	*t* = 1.34	.181	d = 0.04
Visual motor speed	33.17	32.75 ± 7.21	12.55–50.00	35.83	36.70 ± 7.36	8.00–51.18	*t* = 3.35	.001	d = 0.54
Reaction time[a]	0.63	0.64 ± 0.09	0.45–0.91	0.61	0.62 ± 0.10	0.45–1.05	*t* = –1.53	.128	d = 0.21
Impulse control[a]	6	6.36 ± 4.88	0–24	7	6.58 ± 3.56	1–15	*t* = 0.32	.747	d = 0.05
Total symptom score[a]	8.5	13.16 ± 16.08	0–84	4.5	6.53 ± 7.21	0–15	U = 2,178	.008	*r* = 0.21
Boys only									
Verbal memory	82.00	80.83 11.52	48–100	83.00	82.72 ± 10.03	55–99	*t* = 1.20	.234	d = 0.25
Visual memory	73.00	71.30 12.73	33–94	72.00	71.78 ± 13.24	36–98	*t* = 0.25	.800	d = 0.04
Visual motor speed	31.58	31.33 7.00	12.78–45.90	34.88	34.89 ± 7.46	19.30–53.33	*t* = 3.36	.001	d = 0.49
Reaction time[a]	0.64	0.65 0.10	0.47–1.07	0.59	0.61 ± 0.09	0.48–1.03	*t* = –2.53	.012	d = 0.42
Impulse control[a]	7	7.57 5.77	0–29	7	7.81 ± 5.26	0–27	*t* = 0.29	.770	d = 0.04
Total symptom score[a]	6	9.18 11.55	0–53	2	5.25 ± 7.91	0–44	U = 3,259.5	.003	*r* = 0.22

Abbreviation: ImPACT, Immediate Post-Concussion Assessment and Cognitive Testing.

[a] A higher score indicates a lower level of performance or greater symptom severity. Independent-samples *t* tests were used for group comparisons of the 5 ImPACT cognitive test composite raw scores, with Cohen d calculated as the effect size. Mann-Whitney U tests were conducted for group comparisons of the total symptom score, with *r* calculated as a nonparametric effect size.

adjusted significance threshold ($P = .004$, d = 0.33, small effect size). When divided by gender, language-group differences on visual motor speed were observed for boys ($P = .001$, d = 0.49, medium effect size) and girls ($P = .001$, d = 0.54, medium effect size). No group differences were present between language groups for either gender in reaction time, although boys showed a small to medium magnitude of difference ($P = .012$, d = 0.42); those tested in Spanish performed more slowly than those tested in English.

Symptom Reporting

The groups differed in the PCSS total symptom score ($P < .001$, $r = 0.21$, small effect size), with participants tested in Spanish endorsing a greater severity of symptoms. When separated by gender, the language groups displayed similar small effect sizes for boys ($P = .003$, $r = 0.22$) and girls ($P = .008$, $r = 0.21$), and both genders approached the adjusted threshold for statistical significance. We examined gender within each language group via post hoc analysis, which identified no differences in the PCSS total symptom score for participants tested in English (U = 2969.5, $P = .067$, $r = 0.14$) or Spanish (U = 3018, $P = .101$, $r = 0.13$).

We assessed differences in endorsement rates of individual symptoms between the language groups; the results are provided in Table 3 with stratification by gender. Girls tested in Spanish endorsed 10 of the 22 individual symptoms at a greater rate than girls tested in English, and these differences were associated with predominantly large ORs for each symptom (OR range = 1.95–20.00). These symptoms included physical (ie, headaches, vomiting, nausea, balance problems, dizziness, numbness or tingling, and visual problems) and affective (ie, nervousness, sadness, and feeling more emotional) symptoms. The girls tested in English endorsed only 1 symptom (ie, irritability, OR = 2.84, large effect size) at a greater rate than the girls tested in Spanish. Compared with boys tested in English, those tested in Spanish also endorsed 10 of the 22 symptoms at greater rates, all of which were associated with large ORs (OR range = 2.52–7.39). These symptoms included many of the same physical (ie, headache, vomiting, nausea, dizziness, and numbness or tingling) and affective (ie, sadness and feeling more emotional) symptoms as the girls but also included cognitive symptoms (ie, difficulty concentrating and feeling slowed down) and a single sleep-arousal symptom (ie, sleeping more than usual). No symptoms were endorsed more frequently by boys tested in English.

DISCUSSION

Previous researchers[3,8] have compared baseline neurocognitive performances and symptom reporting of athletes tested in English or Spanish and found consistently lower levels of neurocognitive performances and greater symptom severity among those tested in Spanish. We compared a sample of adolescent student-athletes who completed baseline ImPACT testing in Spanish with a sample of student-athletes, matched on age, gender, and academic and health history, who completed their baseline testing in English. The results were in partial alignment with earlier investigations[3,8]: Spanish speakers demonstrated lower performances for the visual motor speed composite score (d = 0.51), slower performances for the reaction time composite score (d = 0.33), and greater symptom severity ($r = 0.22$), all of which were associated with small to medium effect sizes. The magnitude and direction of these group differences were similar when stratified by gender for visual motor speed (boys: d = 0.49; girls: d = 0.54) and total

Table 3. Symptom Reporting Rates by Student-Athletes Tested in English and Spanish[a]

	Girls			Boys		
Symptom	Spanish (n = 76), %	English (n = 76), %	OR (95% CI)	Spanish (n = 93), %	English (n = 93), %	OR (95% CI)
Headache	**56.6**	**25.0**	3.91 (1.96, 7.79)	**39.8**	**10.8**	5.48 (2.52, 11.92)
Vomiting	**27.6**	**3.9**	9.29 (2.64, 32.73)	**19.4**	**3.2**	7.20 (2.04, 25.38)
Nausea	**22.4**	**3.9**	7.01 (1.96, 25.08)	**14.0**	**2.2**	7.39 (1.62, 33.76)
Balance problems	**15.8**	**5.3**	3.37 (1.04, 10.99)	11.8	4.3	2.99 (0.91, 9.74)
Dizziness	**38.2**	**13.2**	4.07 (1.81, 9.16)	**31.2**	**8.6**	4.81 (2.06, 11.23)
Trouble falling asleep	23.7	32.9	1.58 (0.78, 3.22)	19.4	25.8	1.45 (0.73, 2.90)
Fatigue	27.6	30.3	1.14 (0.56, 2.29)	25.8	22.6	1.19 (0.61, 2.34)
Sleeping more than usual	19.7	13.2	1.62 (0.68, 3.88)	**22.6**	**6.5**	4.23 (1.62, 11.04)
Sleeping less than usual	38.2	28.9	1.52 (0.77, 2.98)	35.5	29.0	1.34 (0.73, 2.49)
Sensitivity to light	14.5	13.2	1.12 (0.44, 2.81)	12.9	14.0	1.10 (0.47, 2.55)
Drowsiness	11.8	17.1	1.54 (0.61, 3.84)	8.6	10.8	1.28 (0.48, 3.40)
Sensitivity to noise	9.2	2.6	3.75 (0.75, 18.69)	6.5	2.2	3.14 (0.62, 15.97)
Irritability	*11.8*	*27.6*	2.84 (1.21, 6.71)	15.1	11.8	1.32 (0.57, 3.09)
Nervousness	**47.4**	**31.6**	1.95 (1.01, 3.78)	30.1	19.4	1.80 (0.91, 3.54)
Sadness	**34.2**	**18.4**	2.30 (1.09, 4.87)	**29.0**	**14.0**	2.52 (1.20, 5.26)
Feeling more emotional	**44.7**	**23.7**	2.61 (1.30, 5.23)	**32.3**	**10.8**	3.95 (1.80, 8.68)
Numbness or tingling	**21.1**	**1.3**	20.00 (2.58, 155.14)	**17.2**	**6.5**	3.01 (1.12, 8.09)
Feeling mentally "foggy"	5.3	10.5	2.12 (0.61, 7.36)	6.5	8.6	1.37 (0.45, 4.10)
Feeling slowed down	21.1	10.5	2.27 (0.91, 5.67)	**12.9**	**4.3**	3.30 (1.02, 10.63)
Difficulty concentrating	25.0	23.7	1.07 (0.51, 2.25)	**46.2**	**21.5**	3.14 (1.65, 5.96)
Difficulty remembering	19.7	11.8	1.83 (0.75, 4.49)	14.0	9.7	1.52 (0.62, 3.74)
Visual problems	**27.6**	**5.3**	6.87 (2.23, 21.18)	11.8	6.5	1.95 (0.69, 5.50)

Abbreviation: OR, odds ratio.

[a] Bold values designate symptoms for which student-athletes tested in Spanish had greater odds of endorsement than student-athletes tested in English. Italicized values designate symptoms for which student-athletes tested in English had greater odds of endorsement than student-athletes tested in Spanish. All ORs are oriented so that values above 1.00 indicate greater odds of endorsing the symptom by the language group with a higher endorsement rate.

symptom severity (boys: $r = 0.22$; girls: $r = 0.21$) but showed a greater difference between language groups in reaction time for boys (d = 0.42) than girls (d = 0.21). Two of our authors are bilingual in English and Spanish and identified certain lexical and grammatical concerns in the Spanish-language instructions for the cognitive tests but none that were substantial enough to lead to a misunderstanding of task demands. Group differences observed in neurocognitive composites are not likely attributable to challenges in translation of the ImPACT instructions from English to Spanish.

In comparison with previous work,[1,2,5,7] the magnitudes of the effect-size differences between participants tested in English versus Spanish were smaller for all neurocognitive composites (see Table 4), which could be attributable to the close matching across language groups on numerous demographic characteristics (eg, age, gender), academic history variables (eg, learning disability or dyslexia, history of special education), and health history variables (eg, concussion history, ADD or ADHD, previous treatment for a psychiatric condition, substance use disorder, headaches, or migraines) that have been associated with group differences in cognitive functioning or symptom reporting. Earlier authors matched or excluded participants based on age, ADD or ADHD, learning disability,[3] and educational achievement (ie, high school diploma, college degree).[8] Matching by education led to a reduction in the effect-size differences between language groups,[8] indicating that variables other from language may explain some differences in neurocognitive performance.

Although our effect sizes may be smaller than those of past studies, the differences observed for visual motor speed and reaction time were consistent with many earlier findings[3,4,8,20,21] on linguistic and racial or ethnic differences in baseline ImPACT performances. Previous investigators[3,8] compared participants tested in English and Spanish and found the visual motor speed composite score was associated with the largest group difference. After matching by education, the only group differences between English and Spanish first-language speakers were noted for the visual motor speed composite (for athletes with both high school and college educations) and reaction time composite (for athletes with high school educations only) scores.[8] Group differences in baseline visual motor speed (d = 0.43) and reaction time (d = 0.42) have also been identified between African American and White collegiate athletes, with the former athletes exhibiting lower performances on both composites[4]; however, another examination[20] of participants matched on age, gender, concussion history, and sport affiliation revealed no group differences at baseline between African American and White collegiate athletes. A baseline ImPACT comparison of student-athletes tested in English and Mandarin reflected a small to medium group difference for the visual motor speed composite score (d = 0.37), with higher performances by the participants tested in Mandarin.[21] Among the ImPACT neurocognitive composite scores, visual motor speed appears to differ most consistently across racial or ethnic and linguistic groups, albeit with varying magnitudes of difference. The group differences for the visual motor speed composite score may be related to cultural differences in the value placed on fast performances, such that Spanish-speaking cultures may value response speed less than English speakers in the United States do.[22]

Table 4. **Published Comparisons of Athletes Tested in English and Spanish on ImPACT[a] Extended on Next Page**

ImPACT Component	Jones et al[8]: High School Education, English, Mean	Spanish, Mean	d Value[a]	Jones et al[8]: College Education, English, Mean	Spanish, Mean	d Value[a]
Verbal memory	82.4	80.7	0.17	85.4	80.3	0.51
Visual memory	72.8	67.8	0.37	76.2	70.6	0.41
Visual motor speed	38.3	28.2	1.35	41.6	31.6	1.34
Reaction time[c]	0.6	0.7	1.09	0.6	0.6	0.00
Impulse control[c]	6.8	5.5	0.26	4.4	6.8	0.48
Total symptoms[c]	2.0	3.3	0.13	1.2	6.8	0.54

Abbreviation: ImPACT, Immediate Post-Concussion Assessment and Cognitive Testing.

[a] Jones et al[8] assessed 318 athletes tested in English and 87 athletes tested in Spanish. They did not provide sample sizes for stratified education groups. Ott et al[3] evaluated 11 955 participants from the normative sample who completed ImPACT in English and 2087 participants who completed ImPACT in Spanish. They did not provide sample sizes for the stratified age groups. ones et al[8] did not report SD values, so the average of the SDs for the other 3 samples was used to calculate the effect sizes.

[b] For Ott et al,[3] the Spanish sample was those speaking Spanish who completed ImPACT in Spanish.

[c] A higher score indicates a lower performance or greater symptom severity.

Regarding total symptom reporting, the differences between student-athletes tested in English versus Spanish was significant but of small magnitude ($r = 0.21$). Earlier researchers[3,8] conducted parametric comparisons of symptom reporting despite a likely skewed distribution. Although calculation of a Cohen d effect size may be imprecise and less appropriate for non-normal symptom data, effect sizes for baseline symptom severity differences between athletes tested in Spanish and English in previous studies are provided in Table 4, showing negligible to medium differences (d range = 0.01–0.54). Student-athletes tested in English or Spanish were also compared for the frequencies with which they endorsed individual symptoms. Greater symptom endorsement by student-athletes tested in Spanish was evident for numerous physical (ie, headache, vomiting, nausea, dizziness, numbness or tingling) and affective (ie, sadness, feeling more emotional) symptoms across genders. Within the American Latinx community, physical symptoms have been associated with psychological distress;[23,24] if we infer that the student-athletes tested in Spanish were of predominantly pan-ethnic Latinx heritage (ie, 92.5% of US residents who speak Spanish at home identify pan-ethnically as Hispanic[25]), greater physical symptoms at baseline could reflect a greater degree of baseline psychological distress among the student-athletes tested in Spanish, especially when considered in combination with greater endorsement frequencies of affective symptoms. Within primary care settings, Latinx patients tend to report greater physical and affective symptoms; the latter have been associated with perceived discrimination.[26] Our student-athletes who preferred to communicate in Spanish within a largely English-speaking cultural environment may also have perceived greater discrimination (although we did not measure this factor), which could have contributed to greater psychological distress. The differences in symptom endorsement between groups did not appear to be attributable to the translation of symptoms from English to Spanish. Our 2 bilingual authors (M.A.G.B. and J.M.M.) independently reviewed the symptoms and translated them back to English. Blind to each other's review of the symptom names, neither author found significant discrepancies in meaning between the English-language and Spanish-language symptoms.

A key strength of our work was the focus on a large sample of student-athletes tested in English and Spanish who were matched almost exactly on demographic, academic history, and health history variables that can affect ImPACT performance and symptom reporting.[1,2,5–7] Thus, we controlled for many confounding variables that could have contributed to observed group differences. Still, our investigation also involved limitations. The athletes were not matched on sport, and as shown in Table 1, group differences were present. The most common affiliation for both language groups was soccer, but student-athletes tested in Spanish participated in soccer (42.0%) at a greater rate than those tested in English (17.8%). Authors[27] have begun discussing environmental variables associated with symptom reporting, which may include the culture of a specific sport. Additional limitations pertain to the sampling of student-athletes tested in Spanish and the absence of contextual racial, ethnic, or linguistic data. Although we lacked data on participants' racial and ethnic identities, nearly all US residents from a Spanish-speaking household identify pan-ethnically as Latinx.[25] The full sample of athletes completed ImPACT as part of a larger program of baseline testing at schools in the state of Maine, and the athletes chose to complete the ImPACT battery in Spanish. The reason for this decision cannot be determined based on the available data, but we suspect it was related to a preference for communicating in Spanish rather than English. However, we did not know many characteristics that could have affected the student-athletes' level of proficiency in Spanish, including whether Spanish was their first language and whether they were formally educated in Spanish. We also did not know their proficiency in English. These factors can affect performances on cognitive testing in Spanish, and bilingualism has been specifically associated with better neurocognitive performances on ImPACT and less symptom reporting compared with monolingual Spanish speakers.[3]

The participants in our study elected to complete ImPACT in their preferred language, which may have meant that the participants tested in Spanish were less comfortable communicating in English than their same-aged peers. This preference for communicating in Spanish and taking this baseline battery of tests in Spanish might make our sample fairly unique within the US population. Data collection occurred from 2009 to 2015. In 2011, 15.6% of adolescents between the ages of 15 and 19 in the United States reported speaking Spanish at home, and of

Table 4. Extended From Previous Page

Ott et al[3]: 13- to 15-year-olds			Ott et al[3]: 16- to 18-year-olds			Current Study		
English, Mean ± SD	Spanish,[b] Mean ± SD	d Value	English, Mean ± SD	Spanish,[b] Mean ± SD	d Value	English, Mean ± SD	Spanish, Mean ± SD	d Value
83.6 ± 9.5	81.0 ± 9.7	0.27	84.7 ± 9.7	81.5 ± 10.0	0.32	83.8 ± 9.5	82.1 ± 11.4	0.17
72.7 ± 13.2	69.8 ± 14.2	0.21	74.0 ± 13.2	69.8 ± 14.4	0.30	73.0 ± 12.9	71.4 ± 13.5	0.12
36.6 ± 6.7	29.4 ± 8.1	0.97	39.2 ± 6.9	30.8 ± 8.4	1.09	35.7 ± 7.5	32.0 ± 7.1	0.51
0.61 ± 0.08	0.65 ± 0.10	0.44	0.59 ± 0.08	0.64 ± 0.11	0.52	0.62 ± 0.09	0.65 ± 0.09	0.33
–	–	–	–	–	–	7.3 ± 4.6	7.0 ± 5.4	0.05
5.3 ± 8.9)	7.6 ± 11.5	0.22	6.3 ± 9.9	6.4 ± 9.3	0.01	5.8 ± 7.6	11.0 ± 13.9	0.46

those, 82.7% reported speaking English "very well," meaning that only 2.7% of the total adolescents surveyed were Spanish speakers without a high level of self-reported English proficiency.[25] These individuals may have had different acculturative experiences, which have been associated with performance on neuropsychological tests.[10–12] For example, among Spanish-speaking adults in the United States, acculturative experiences outside of the United States, such as being born or educated internationally, were associated with reduced fluid ability scores but higher crystallized ability scores when evaluated in Spanish.[28]

The current findings revealed small to medium differences in ImPACT neurocognitive performances and symptom reporting between student-athletes tested in English versus Spanish, who were matched on age, gender, and academic and health history. Although small to medium in magnitude, the group differences were not negligible and could have meaning for clinical practice. First, regarding symptom reporting, symptom severity was modestly different between groups, but the rates of individual symptom endorsement appeared quite different, especially for physical and affective symptoms. Clinicians involved in the management of concussions in student-athletes who prefer to communicate in Spanish should be mindful that greater symptom reporting may occur among this group and that more physical symptoms could be related to psychological distress. Second, student-athletes tested in Spanish also had lower mean performances on all neurocognitive composite scores, but the only significant group differences were for visual motor speed and reaction time. The group differences in visual motor speed equated to 0.5 SD in magnitude ($d = 0.51$), which could lead to different interpretations of performances in clinical practice: a student-athlete performing at the 31st percentile (ie, average) and another performing at the 16th percentile (ie, low average) are separated by 0.5 SD. When interpreting visual motor speed and reaction time performances, clinicians should recognize that performances may be, on average, lower than expected among student-athletes tested in Spanish. Consistent with previous research comparing White and Latinx athletes,[3] White and African American athletes,[4] and athletes tested in English versus Mandarin,[21] the largest group difference between athletes tested in English versus Spanish was for visual motor speed, indicating that this composite score may be the most sensitive to racial or ethnic and linguistic differences among athletes.

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