Exploring Baseline Concussion-Assessment Performance in Adapted Wheelchair Sport Athletes

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Context: With growing awareness of and advocacy for including individuals with disabilities in sport, implementation of concussion-assessment and -management strategies is warranted. Limited research is available on concussion assessment in adapted wheelchair sport athletes.

Objective: To examine baseline symptom reporting, computerized neurocognitive testing, and a modified balance scoring system in adapted athletes. A secondary objective was to provide preliminary normative data for this population.

Design: Cross-sectional study.

Setting: University athletic training room and computer laboratory.

Patients or Other Participants: Twenty-one athletes (age = 22.1 ± 3.0 years) from 1 institution's collegiate adapted athletics program.

Main Outcome Measure(s): Athletes completed baseline Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) and the Wheelchair Error Scoring System (WESS) before the start of their respective seasons. Symptom reporting variables consisted of total symptoms, symptom severity scores, and baseline symptom factors (eg, vestibular-somatic, sleep arousal, cognitive-sensory, and affective). We analyzed ImPACT composite scores of verbal memory, visual memory, visual motor processing speed, and reaction time and impulse control to determine neurocognitive function. Balance performance was quantified using the WESS condition and overall errors.

Results: Compared with normative reference values, 17 (81%) of adapted athletes reported greater symptoms and 20 (95%) performed at or below average on at least 1 neurocognitive composite score. Mean errors on the WESS were 3.14 ± 2.9, with 81% committing ≥1 error. Sex differences were not present for symptoms, neurocognitive testing, or balance measures.

Conclusions: Our findings provide context for baseline performance in adapted athletes and help to further develop the WESS as an assessment of balance in these athletes.

Key Words: disability, balance, baseline testing, traumatic brain injuries

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Key Points

- Baseline concussion assessment in unique populations, including athletes living with disabilities, is warranted.
- Adapted athletes reported more symptoms and performed worse on computerized neurocognitive testing compared with normative reference values at baseline.
- A preliminary error scoring system for measuring balance in adapted athletes has been established, and error performance at baseline was quantified.

The number of individuals with disabilities participating in organized sport and recreational activity continues to increase and expand globally[1] due to the resulting benefits, including physical activity, physical fitness, and self-concept.[2] Growing awareness of the capabilities of individuals with disabilities has fueled increases in programs such as Special Olympics, Paralympics (Olympic level), and, more recently, adapted athletics (collegiate level).[3] These athletics programs serve athletes with an array of disabilities, such as spinal cord injuries, limb deficiencies (amputation, dysmelia, congenital deformity), central neurologic injuries (cerebral palsy, spina bifida, stroke), and visual impairments.[4,5] Increased participation rates among individuals with disabilities are universally supported but carry the potential for higher injury rates.[6,7] During the 2012 Summer Paralympic

Games, the overall injury incidence rate was 12.7 injuries per 1000 athlete-days, with 2.2% of those injuries to the head/face and 5.7% to the neck.[8] In 2018, an overall injury rate of 68.9 injuries per 1000 athlete-days occurred during the Wheelchair Basketball World Championships, with 1.0% of those injuries to the head and 16.0% to the neck.[9] The increasing rates of participation and injuries in athletes with disabilities also prompt general concerns over sport-related concussions. To date, a notable dearth of literature has addressed this pressing medical concern among disabled and adapted athletes. Authors[4] of one of the earliest studies of this population examined concussion incidence rates and reporting in wheelchair basketball athletes. Approximately 20% of participants in wheelchair basketball described a previous concussion; 6% had sustained a concussion in their most current sport season.

By sex, 30% of women and 15% of men gave a history of concussion.[4] Among wheelchair basketball participants who sustained concussions, 44% neglected to report their injury to a medical professional or coach, whereas 54% failed to refrain from activity while they experienced concussion symptoms.

For better evaluation and management of concussion, concussion protocols for nondisabled people have been implemented in adapted populations. Weiler et al[10] examined baseline Sport Concussion Assessment Tool 3 (SCAT3) performance in soccer athletes with and without disabilities. Male athletes with cerebral palsy had a greater number of baseline symptoms, higher total severity scores, and worse immediate memory and Balance Error Scoring System (BESS) scores than male athletes without a disability. Although this work constitutes an important step in improving health care for this population, the results are limited to more nondisabled, functional athletes; the performance of athletes who use wheelchairs for sport is unknown.

How concussion consensus statement recommendations for comprehensive and multifaceted assessment, including mental status, cognitive function, gait, and balance,[11] are applicable to adapted athletes is unclear. The International Paralympic Committee[6] expressed the need for research on concussion-assessment tools in adapted and disabled athletes to address the lack of evidence and ensure that modifications and validations of these tools extend the existing instruments rather than become separate entities. Further, the committee recommended the development of appropriate balance tests for this population.[6] Weiler et al[10] studied memory using the SCAT3, yet computerized neurocognitive testing offers deeper assessment of the neurocognitive and neurobehavioral sequalae of concussion by measuring domains of learning, retention, working memory, impulse inhibition, and visual motor speed.[12] Previous researchers[13] identified psychomotor impairment among persons who use a wheelchair after spinal cord injury. Di Russo et al[14] observed that participants with lower limb impairments had a longer upper limb motor reaction time to visual stimuli than nondisabled nonathletes; however, how domains of memory or attention are influenced on computerized neurocognitive tests in this population remains unknown. Additionally, symptoms were previously measured as total number of symptoms and symptom severity scores or a sum of the total number of symptoms. Investigation into symptom subtypes and factors may provide further information on specific domains or impairments at baseline and postconcussion.

Gait and balance testing also poses a challenge in the adapted sports population, as no widely accepted, validated tool for sideline or clinical assessment of balance and postural stability in adapted and wheelchair-using athletes is available.[15–17] In 1 study,[18] a seated reach test was administered to measure trunk balance in wheelchair-using basketball players. However, a seated reach test may be more indicative of hamstrings and lumbopelvic flexibility than balance and postural stability. The BESS,[19] which has been the standardized balance assessment on the SCAT3 and SCAT5 tools, is performed using a series of standing positions, with tasks of double-legged, single-legged, and tandem stances on stable and unstable surfaces, making it an inappropriate test for a wheelchair-using athlete.

Development of a modified balance test to measure balance and postural stability in athletes who use wheelchairs and athletes with lower extremity disabilities is warranted. To best replicate the vestibular and somatosensory inputs required during balance and postural stability, we implemented a modified balance assessment, the Wheelchair Error Scoring System (WESS), consisting of stable and unstable surfaces across multiple positions.[20] Although the WESS has undergone preliminary validation and reliability testing,[20] our goals were to help researchers better understand the test at baseline and aid in the advancement of the WESS test to the clinical setting. To bridge the gaps in the concussion-assessment literature and the validation of applicable tools for an adapted population, we examined baseline symptom reporting and symptom factors, computerized neurocognitive testing, and WESS performance in collegiate adapted athletes.

METHODS

Participants

A total of 21 adapted athletes (11 men [52%] and 10 women [48%]), aged 18 to 31 years, completed baseline testing. The athletes represented men's basketball (n = 7), women's basketball (n = 7), and coeducational tennis (n = 7) teams. One participant's data were excluded from the balance analyses due to the inability to perform the test but were included in the symptom and neurocognitive testing analyses. Prior concussions were reported by 5 (24%) participants, with 16 (76%) reporting no such history. All participants were deemed healthy to compete in collegiate adapted athletics with no restrictions by a team physician. No participants had visual impairments that would have jeopardized performance in sport or on computerized neurocognitive testing. Institutional review board approval from The University of Alabama was granted, and informed consent was obtained before baseline testing.

Measures

Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT Applications, Coralville, IA) was implemented to capture symptom reporting and the neurocognitive functions of verbal memory, visual memory, visual motor processing speed, reaction time, and impulse control. Participants self-reported symptoms on the ImPACT using a 21-item, concussion-symptom scale, rating symptoms from 0 (none) to 6 (severe) on a Likert scale. Symptoms were classified based on the total number of symptoms, symptom severity (sum of all symptoms), and baseline symptom factors. Although the total number of symptoms and symptom severity scores were exported from ImPACT, baseline symptom factor classifications, described by Kontos et al,[21] were calculated to identify the specific symptoms being reported. Baseline factors are provided in Table 1.[21] Higher composite scores for verbal memory, visual memory, and visual motor processing speed and a lower score for reaction time indicate better performance. Impulse control is an ImPACT variable that measures the number of errors on testing and is useful in determining test validity, with lower scores indicating better impulse control.

Table 1. Baseline Symptom Factors

Vestibular-Somatic	Sleep-Arousal	Affective	Cognitive-Sensory
Headache	Fatigue	Irritability	Sensitivity to light
Nausea	Drowsiness	Sadness	Sensitivity to noise
Vomiting	Trouble falling asleep	Nervousness	Feeling slowed down
Balance	Sleeping more or less than usual	Feeling more emotional	Mentally foggy
Dizziness			Difficulty concentrating
			Difficulty remembering
			Vision problems

To accommodate athletes with a lower extremity disability, the BESS was modified to provide a more functional assessment with the seated participant using a wheelchair. For the WESS, an individual sits with the hands on the hips or wheels under 6 conditions of 20 seconds each: 3 positions (seated, balance disk, wheelie) × 2 visual inputs (eyes open and closed; Figure).[20] The seated position consists of sitting on a firm surface or table with the legs over the edge of the surface or table. The next position involves sitting on a balance disk to replicate the BESS unstable surface. The third position consists of a wheelie (with only the 2 back wheels on the ground), which is a normal everyday task that allows for community ambulation (eg, going up and down curbs) that wheelchair users can accomplish with minimal difficulty. The test conditions were selected to manipulate the 3 systems involved in postural stability: visual, vestibular, and somatosensory. The scoring of the WESS is based on the number of errors committed during each condition, mirroring the BESS scoring (Table 2).[19] In a preliminary study, the WESS demonstrated high intratester (intraclass correlation coefficient [ICC] = 0.65, 1.00), intertester (ICC = 0.69, 0.86), and test-retest (ICC = 0.95) reliability.[20] Participants' performance of the WESS on a forceplate to quantify seated postural sway and provide the 95% confidence ellipse area indicated that concurrent validity of the WESS was in the range of 0.55 to 0.74.[20]

Testing Procedures

Adapted athletes completed the baseline ImPACT in a computer laboratory and the WESS in the athletic training room before the start of their competitive season. The ImPACT and WESS were completed on separate days and in a counterbalanced manner; the ImPACT required approximately 20 minutes, and the WESS, 3 minutes. The principal investigator (R.N.M.) administered the ImPACT test to each athlete and was the sole administrator and interpreter of the WESS test and scoring.

Data Analysis

General descriptive (ie, means, SDs, frequencies) and inferential statistics were used to summarize all demographic information, symptoms, computerized neurocognitive test results, and balance performance. Normative values were produced for the sample and stratified by sex. A series of analysis-of-variance and Mann-Whitney U tests were conducted to determine sex differences for symptoms, neurocognition, and balance. Exact significance
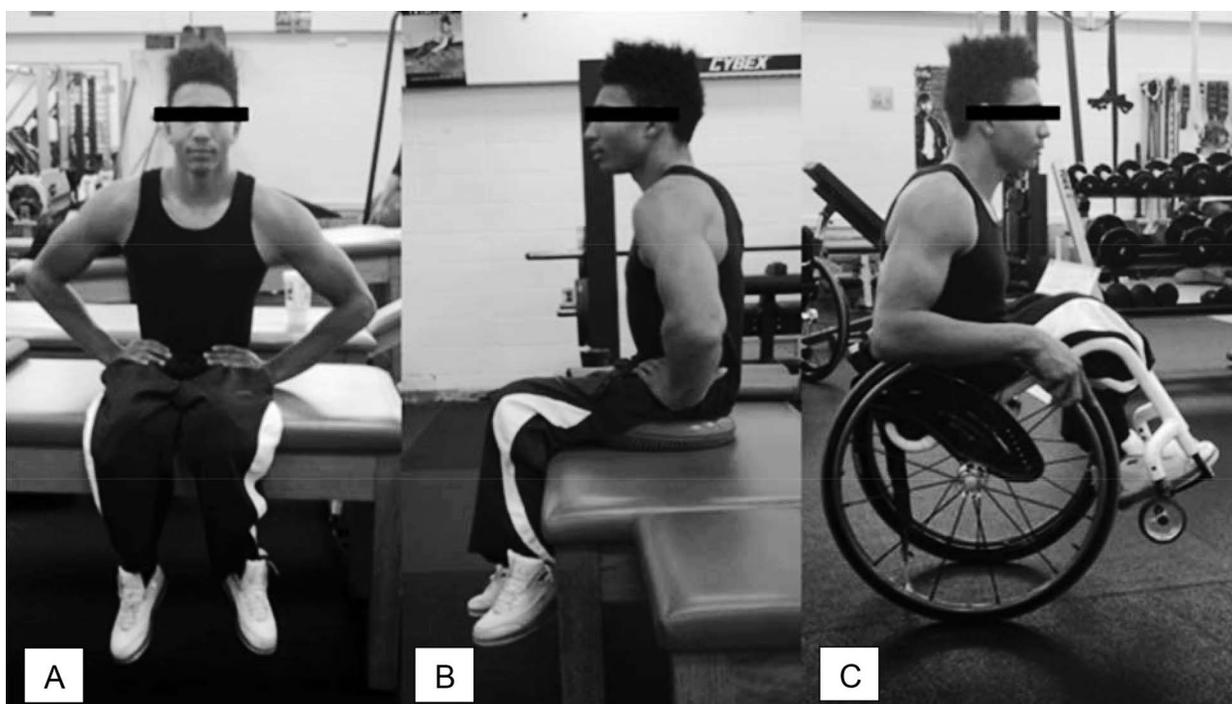
Figure. Positioning and stances on the Wheelchair Error Scoring System: A, seated on firm surface; B, seated on balance disk (unstable surface); C, wheelie.

Table 2. Wheelchair Error Scoring System Error Scoring[a]

Types of Errors

1. Hands lifted off the iliac crest
2. Opening of eyes (eyes-closed condition only)
3. Moving trunk into >30° flexion or abduction
4. Coming out of the wheelie
5. Changing grip during the wheelie task
6. Hands lifted off wheels during the wheelie task
7. Remaining out of position >5 s

[a] One point is added for each error during the six 20-second tests. A maximum of 10 errors are counted for any single condition.

values were used instead of asymptotic values due to the small sample size. Composite scores on ImPACT were compared with normative ImPACT values outlined in the Concussion Assessment, Research and Education (CARE) Consortium Report.[22] We selected the CARE Consortium results for comparison because it is the largest prospective concussion study to date, with recent, robust neurocognitive outcomes using ImPACT. Additionally, other normative references and ImPACT norms were based on smaller sample sizes and are outdated. Graded category criteria for ImPACT performance were classified as *impaired* (<second percentile), *borderline* (third to ninth percentile), *low average* (10th to 24th percentile), *average* (25th to 75th percentile), *high average* (76th to 90th percentile), *superior* (91st to 98th percentile), or *very superior* (>99th percentile). In addition, interitem correlations were conducted between WESS conditions. The criterion for interpreting the strength of the correlation was *weak* (<0.5), *moderate* (0.5–0.7), or *strong* (>0.7). A linear regression was calculated to further validate the relationship between balance symptoms and WESS performance.

RESULTS

Of the 21 participants, 18 (86%) reported fewer than 10 total symptoms: 9 (43%) endorsed ≥3 symptoms and 2 (>1%) described no baseline symptoms. Symptom scores and factor scores are shown in Table 3. Overall ImPACT performance is noted in Table 4. No differences by sex were present for symptom reporting, ImPACT composite scores, or WESS scores.

When we compared ImPACT performance by sex (Table 4) to normative ImPACT values for university men and women from the CARE Consortium,[22] men performed in the 10th to 24th percentile on verbal memory and 25th to 75th percentile on visual memory, visual motor processing speed, and reaction time. Women also performed worse than expected relative to normative values, scoring in the third to ninth percentile on verbal memory, 10th to 24th

percentile on visual memory, and 25th to 75th percentile on visual motor processing speed and reaction time.

Overall, WESS scores were minimal to moderate, with 1 (<1%) participant committing errors in the seated conditions (ie, eyes open and closed), 7 (35%) on the balance disk conditions, and 15 (71%) on the wheelie conditions. The number of participants who committed an error during each condition and task and mean error scores are shown in Table 5. No sex differences were observed during the seated, balance disk, or wheelie tasks or for overall WESS total errors ($P = .05$).

Interitem correlations for WESS conditions revealed moderate to strong strengths of association, with a strong correlation between total WESS errors and the balance disk ($r_s = 0.73$, $P < .001$) and wheelie ($r_s = 0.56$, $P = .008$) conditions. Weak correlations existed between the seated and balance conditions ($r_s = 0.40$, $P = .08$) and the seated condition and total WESS errors ($r_s = 0.34$, $P = .13$; Table 6). Linear regression revealed that self-reported balance symptoms predicted total WESS scores, despite explaining 23% of the variance ($P = .02$). When we examined balance symptoms by test condition, they predicted the total balance disk errors ($P = .001$, $r^2 = 0.55$) but not the total seated ($P = .18$) or wheelie ($P = .89$) errors.

DISCUSSION

This study is the first to examine a multifaceted baseline assessment in adapted, wheelchair-using athletes. To date, the medical literature has largely neglected this population beyond an examination of incidence rates in competitive events. Despite that, medical professionals must provide a high level of care to concussed athletes with a limited understanding of how best to evaluate the injury. Basing our approach on the literature for the nondisabled, we implemented a symptom and neurocognitive evaluation consistent with that used in nondisabled athletes. The physical limitations of wheelchair athletes preclude the use of the BESS, but the WESS appears to be a viable alternative.

We found that the adapted athletes reported more baseline symptoms than the normative reference values for collegiate athletes.[23] Collegiate athletes described 1.75 symptoms at baseline (men = 1.67 versus women = 1.93), whereas the athletes in our study endorsed 5.00 symptoms (men = 4.55 versus women = 5.50). Our athletes also had both higher total symptom scores than soccer athletes with cerebral palsy (5.00 versus 1.5 total symptoms) and higher symptom severity scores (8.5 versus 2.5).[10] The reasons for these differences are unclear and may vary depending on the cohort's specific impairments. This is the first study to attempt to categorize reported symptoms into baseline factors, which may provide further insight into the types of

Table 3. Symptom Scores and Symptom Factors for the Sample and by Sex (Mean ± SD)[a]

Symptom Variable or Factor	Sample (N = 21)	Men (n = 11)	Women (n = 10)
Total symptoms, No.	5.00 ± 4.8	4.55 ± 3.6	5.50 ± 6.0
Symptom severity (range = 0–126)	8.57 ± 10.9	7.36 ± 6.5	9.90 ± 14.7
Vestibular-somatic (range = 0–30)	1.57 ± 2.2	1.36 ± 1.5	1.80 ± 2.9
Sleep-arousal (range = 0–30)	3.24 ± 2.2	3.18 ± 2.8	3.30 ± 3.3
Affective (range = 0–24)	1.19 ± 2.9	0.45 ± 0.8	2.00 ± 4.0
Cognitive-sensory (range = 0–42)	2.57 ± 4.1	2.36 ± 2.6	2.80 ± 5.5

[a] No sex differences existed for any symptom variables.

Table 4. ImPACT Composite Scores for the Sample, by Sex, and CARE Consortium Norms (Mean ± SD)[a]

ImPACT Composite Measure	Sample (N = 21)	Men (n = 11)	Women (n = 10)	CARE (N = 15 681)
Verbal memory	79.29 ± 13.5	79.00 ± 9.8	79.60 ± 17.2	86.7 ± 10.8
Visual memory	70.10 ± 15.0	75.27 ± 10.2	64.40 ± 17.7	77.0 ± 13.6
Processing speed	37.83 ± 13.5	37.00 ± 4.0	38.73 ± 7.0	41.1 ± 6.6
Reaction time	0.62 ± 0.8	0.62 ± 0.1	0.61 ± 0.5	0.59 ± 0.1
Impulse control	6.76 ± 6.2	5.73 ± 4.2	7.90 ± 7.9	Not provided

Abbreviations: CARE, Concussion Assessment, Research and Education; ImPACT, Immediate Post-Concussion Assessment and Cognitive Testing Applications (Coralville, IA).

[a] No sex differences existed for any ImPACT composite scores.

symptoms being reported at baseline. One consistency between the symptom factors and normative values was that nondisabled collegiate athletes described fatigue and drowsiness as the most common symptoms at baseline, which are considered the sleep-arousal factor. In the sleep-arousal cluster, our participants had the highest mean scores for both men and women. Although this seems intuitive (ie, collegiate athletes endorsed sleep-arousal factors due to their social and physical environments not being conducive to restorative sleep[24]), understanding the types of symptoms may enable clinicians to better implement recovery and management techniques while also having more in-depth symptom information regarding baseline and postconcussion outcomes.

Relative to comparable values for university athletes from the CARE Consortium,[22] using graded category classifications, we observed that overall computerized neurocognitive performance on the ImPACT test was borderline impaired (third to ninth percentile) to average (25th to 75th percentile) in adapted athletes. Further, using approximate classification ranges for index scores, we classified adapted male athletes as low average on verbal memory and average on visual memory, visual motor processing speed, and reaction time. Women were classified as borderline impaired on verbal memory, low average on visual memory, and average on visual motor processing speed and reaction time. These results are similar to those of Weiler et al,[10] who reported lower immediate memory scores among athletes with cerebral palsy relative to control participants. Although the ImPACT uses a more advanced psychometric battery for evaluating memory, these findings reflect the deeper neurocognitive deficits that are evident at baseline with a more advanced cognitive function test. Our results also support sensory deprivation research, which suggested inhibited somatosensory input to the central

nervous system after spinal cord injury, negatively affecting cortical reactivity and cognitive task efficiency[25] and leading to longer latencies during visual stimuli in individuals with amputations.[26]

We also sought to develop and understand the WESS test as an assessment of postural stability in athletes who use a wheelchair for sport. Increasing difficulty (more errors) was demonstrated on the dynamic surface (balance pad or disk) among wheelchair-using athletes, a trend also noted in nondisabled collegiate athletes on the BESS.[27] The WESS uses a single upright posture, as opposed to 3 distinct stances; therefore, the results of the WESS closely resemble those of double-legged stance for overall postural stability in a neutral position. Additionally, all BESS conditions are completed with the eyes closed, whereas the WESS uses eyes open and eyes closed to modify the conditions and increase the challenge for the athletes. The seated, eyes-closed condition of the WESS, which most resembles the firm-surface, double-legged condition of the BESS, produced similar results to normative collegiate values, with 0.05 and 0.02 errors, respectively.[27] The balance disk was chosen to resemble a dynamic surface, similar to the foam surface on the BESS, yet scores were higher than normative collegiate values on the double-legged foam condition of the BESS (0.11 errors). This could be because the participants relied on a stable chair for sport and may have relied on their upper extremity to a greater extent when on an unstable surface. They were given a standardized period of time (up to 1 minute) to acclimate and adjust themselves as needed on the balance disk before beginning the trial. Once the participant was stable and reported being ready, testing began. This could have been the first exposure to this type of condition, which may have influenced performance. Compared with results of athletes with cerebral palsy on the modified firm-surface BESS, the total errors of adapted athletes in this study were lower, despite the unstable surface.[10] Differences between the WESS and BESS can largely be attributed to the differences in stances but also in error scoring between the tests.

Table 5. Wheelchair Error Scoring System (WESS) Performance by Condition[a]

WESS Variable	No. (%) Committing ≥1 Error	Minimum-Maximum	Mean ± SD
Seated, eyes open	0 (0)	0-0	0.00 ± 0.0
Seated, eyes closed	1 (>1)	0-1	0.05 ± 0.2
Balance disk, eyes open	4 (20)	0-3	0.35 ± 0.8
Balance disk, eyes closed	7 (35)	0-5	1.00 ± 1.5
Wheelie, eyes open	4 (19)	0-2	0.24 ± 0.5
Wheelie, eyes closed	14 (67)	0-6	1.57 ± 1.7
Total WESS errors	17 (81)	0-11	3.14 ± 2.9

[a] One participant's data were excluded from the seated and balance disk conditions but included for the wheelie condition: seated and balance disk = 20, wheelie = 21, total errors = 21.

Table 6. Intercondition Correlations for the WESS (Wheelchair Error Scoring System)

	Condition		
WESS Variable	Seated	Disk	Wheelie
Seated condition	—		
Balance disk condition	0.40	—	
Wheelie condition	−0.28	−0.04	—
Total WESS errors	0.34	0.73[a]	0.56[a]

[a] $P < .05$.

Our study was not without limitations. First, we recruited a convenience sample from a single institution's collegiate adapted athletics program. Thus, the findings may only be applicable to these athletes with their specific impairments. Additionally, neither the participants' medical diagnoses (eg, cerebral palsy, spina bifida) nor any confounding variables, such as prior traumatic brain injury, medications at the time of testing, or attention disorders, were taken into account, so the results may not be generalizable to individual disability classifications. As previously mentioned, the WESS uses the ilium as a base of support for postural stability, as opposed to the feet and lower extremities for the BESS. Trunk strength and motor coordination were not studied but may warrant future consideration. Given that the WESS incorporates an eyes-open and eyes-closed task for each condition, the modified clinical test for sensory interaction on balance[28] may be more suited for comparing normative values, which use firm and foam surfaces with the eyes open and closed.[29] During the eyes-open task on the firm surface, no sensory systems are compromised, and visual, vestibular, and somatosensory input is available, whereas the eyes-closed task compromises the visual system. During the eyes-open task on the balance disk, somatosensory input is compromised, leaving the individual to rely on visual and vestibular input. In the eyes-closed task on the balance disk, only vestibular input is available due to compromised visual and somatosensory input, which further reflects static and dynamic postural-control variables.[29] A balance disk was selected to create an unstable environment rather than the foam pad used in the BESS test because the participants typically used foam padding or similar materials in their wheelchairs throughout the day. The balance disk created a more challenging environment that required further reliance on sensory integration.

Future researchers should aim to calculate postural-sway measures using forceplate technology and accelerometry to determine errors from human scoring. Self-reported symptoms and neurocognitive assessments within ImPACT may not provide sufficient evidence to support the reliability and validity of these inferences in individuals with disabilities. Because no data on athletes who use wheelchairs are readily available for these tools, we offered a preliminary comparison with normative values. Additionally, as participants with visual impairments are common in adapted sports, it is unclear how people with such impairments would perform on a baseline assessment using ImPACT or other concussion-screening tools that rely on vision, such as the Vestibular/Ocular Motor Screening or King-Devick test. Research is also needed to address performance on postinjury assessment and follow-up (eg, 1 week, 1 month) in athletes who use wheelchairs. Lastly, future investigators should consider comparing comprehensive (eg, symptoms, balance, neurocognition, vestibular) concussion assessments among disability classification grades (1.0–4.5; lower grades represent greater disability) for functionality. Consensus recommendations for concussion management and return to participation may pose a challenge for wheelchair basketball and tennis athletes because of the inability to administer standardized balance assessments and unclear wheelchair-specific return-to-play progressions (eg, noncontact training drills, full-contact practice). Special considerations may be needed for concussion-assessment and -management and return-to-participation guidelines in adapted sport athletes.

In conclusion, we aimed to provide a preliminary understanding of adapted (wheelchair) athletes' performance on baseline symptom reporting and computerized neurocognitive and balance testing using a newly developed test for athletes with lower leg or spinal disabilities who use a wheelchair for sport. As baseline symptoms and neurocognitive deficits were apparent, we recommend the use of multifaceted baseline and postconcussion assessment strategies to aid in better diagnosis and management of sport-related concussion among adapted athletes.

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