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Collegiate Adapted Athlete Baseline Performance on the Vestibular/Ocular Motor Screening

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Context: Concussion assessment in adapted and parasport athletes has continued to evolve with growing considerations in parasports, but little is known about vestibular/ocular performance assessment in this sample.

Objective: To examine baseline performance on the Vestibular/Ocular Motor Screening (VOMS) in collegiate adapted athletes. A secondary objective was to investigate the role of sex, history of concussion, and functional classification on baseline measures.

Design: Cross-sectional study.

Setting: University adapted athletics facility.

Patients or Other Participants: Fifty-four collegiate adapted athletes (age = 21.19 ± 2.6 years) from multiple institutions' adapted athletics programs across the United States.

Main Outcome Measure(s): Adapted athletes completed a baseline VOMS assessment while at the host university for in-season competition and tournaments. Independent variables were sex, history of concussion and functional classification (1.0–4.5 at 0.5 intervals). Vestibular/Ocular Motor Screening performance consisted of pretest symptoms (headache, dizziness, nausea, and fogginess) and postitem (eg, smooth pursuits, saccades) symptom provocation or change from pretest scores.

Results: A proportion of 50.9% reported zero symptom provocation on the VOMS, with 72% having no pretest symptoms. No sex differences were noted on the VOMS ($P > .05$); however, adapted athletes with a history of concussion reported greater VOMS provocation on horizontal saccades ($P = .008$) than those with no history. Higher functional classifications (2.0–4.5) reported greater provocation on horizontal saccades ($P = .010$), horizontal and vertical ($P = .043$ and .048) vestibular/ocular reflex, and vestibular/ocular reflex cancellation ($P = .036$) than 1.0–1.5 athletes.

Conclusions: Our findings provide context for baseline VOMS performance in collegiate adapted athletes and identifying modifiers at baseline. Special consideration is warranted on vestibular and oculomotor assessment in adapted and parasport athletes with a history of concussion and higher functional classifications.

Key Words: baseline testing, disability, traumatic brain injuries

Key Points

- Vestibular/ocular reflex tasks were more symptom provoking in adapted athletes with higher functional classifications, indicating athletes with less trunk stability and movement in varying planes may be more protected from vestibular provocation, at the expense of inefficient vestibular/ocular pathways.
- Higher saccadic symptom provocation was associated with prior concussion and higher functional classifications.
- Most adapted athletes are symptom free both before and after each Vestibular/Ocular Motor Screening item.
- Sex differences do not appear to modify baseline Vestibular/Ocular Motor Screening in collegiate adapted and wheelchair sport athletes.

Concussion in parasport was added as a key element to the 6th Consensus Statement on Concussion in Sport because common evaluation tools are not valid in this population due to the potential of the individual's underlying impairment and pathology acting as a modifier of clinical presentation and recovery.[1] Underlying inhibition of somatosensory input to the central nervous system after spinal cord injury (SCI) may negatively affect cognitive efficiency and visual stimuli, also potentially explained by motor function adaptation and preservation after neurologic injury as well as long-term and permanent neurological consequence.[2–4] This comes after the initial position statement from the Concussion in Para Sport Group recognizing the need for case-by-case decision-making and a call for future research to explore performance on common concussion assessment tools to further understand potential modifications that may be needed.[5] In this statement, Weiler et al delineated which aspects of the Sport Concussion Assessment Tool (SCAT) need additional considerations or should not be used for para-athletes by pathology (eg, spina bifida, SCI, cerebral palsy [CP]).[5] For most, caution is needed when evaluating cognition and balance on the modified Balance Error Scoring System, which is validated in individuals without SCI and neurological impairments. Given recent findings that athletes with disabilities present with greater baseline symptoms and worse cognition and balance than those without disability, further exploration into multifaceted assessment measures has been warranted.[6]

To address these calls for investigation, Moran et al examined baseline concussion assessment in collegiate adapted wheelchair sport athletes from the United States on a battery comprising of symptoms, computerized neurocognition, and postural control.[7] When comparing adapted athletes' baseline presentation with normative values in collegiate athletes from the National Collegiate Athletic Association (NCAA)–Department of Defense Concussion Assessment, Research and Education (CARE) Consortium, adapted athletes reported greater symptoms and had worse memory, processing speed, and reaction time. Postural control was measured using a wheelchair version of the Balance Error Scoring System, the Wheelchair Error Scoring System, revealing increasing errors when balancing on a balance disk and performing a wheelie task.[8] These findings provided preliminary evidence on concussion assessment in adapted athletes; however, further research was needed to understand other common assessment tools but across a national sample of adapted athletes. Alongside the development and dissemination of the 6th Consensus Statement on Concussion in Sport was the update to the Sport Concussion Assessment Tool (SCAT6) and new integration of the Office Assessment Tool (SCOAT6).[9,10] The SCAT6 has been updated to now include an expansion from 5- to 10-word immediate memory and optional dual-task tandem gait. The SCOAT6 was developed to serve as an evaluation tool 72 hours after a sport-related concussion (SRC).[10] The SCOAT6 features the evaluation items from the SCAT6, with the addition of orthostatic vital signs, cervical spine assessment, and a modified version of the Vestibular/Ocular Motor Screening (mVOMS/VOMS), a symptom provocation tool for concussion.[11–13] The mVOMS eliminates the convergence, vertical saccades, and vertical vestibular/ocular reflex (VOR) tasks from the full VOMS. While clinical utility and investigation into the VOMS has increased due to the tool's ability to improve acute concussion identification, performance in adapted and parasport athletes remain unexplored.[12] Without prior investigation in this sample, coupled with the inclusion of the VOMS on the SCOAT6, a comprehensive investigation into baseline VOMS performance is warranted.

Given that the Concussion in Para Sport Position Statement calls for future research to inform potential modifications needed, modifying factors that are unique to these athletes, such as specific pathologies and functional classification, need investigating.

Addressing concussion assessment in an understudied sample is imperative to understand clinical baseline measures and the role of common modifiers, such as sex and concussion history, in adapted athletes.[14–18] Therefore, the purpose of this study is 2-fold: (1) to examine baseline performance of the VOMS in a national sample of collegiate adapted athletes and (2) to investigate the potential modifying role of sex, history of concussion, and functional classification on baseline measures.

Table 1. Demographics of the Sample[a]

Age, y	
Mean ± SD	21.19 ± 2.6
Male only	21.58 ± 2.5
Female only	20.82 ± 2.6
Range (min–max)	10 (18–28)
Biological sex	
Male (%)	26 (48.1)
Female (%)	28 (51.9)
Concussion history	
No history	31 (57.4)
Prior history	23 (42.6)
1 prior concussion	10 (43.5)
2 prior concussions	11 (47.8)
3+ prior concussions	2 (8.7)
Diagnosed or treated for headache disorder or migraines	
Yes	6 (11.1)
No	48 (88.9)
Diagnosed with learning disability or dyslexia	
Yes	7 (13.0)
No	47 (87.0)
Diagnosed with ADD/ADHD	
Yes	9 (16.7)
No	45 (83.3)
Diagnosed with depression, anxiety, or psychiatric disorder	
Yes	13 (24.1)
No	41 (75.9)
Functional classification	
1.0—no active trunk movement	9 (16.7)
1.5	11 (20.4)
2.0—active upper trunk movement	9 (16.7)
2.5	8 (14.8)
3.0—active upper and lower trunk movement	8 (14.8)
3.5	4 (7.4)
4.0—maximal trunk movement with weakness	3 (5.6)
4.5—maximal trunk movement with no weakness	2 (3.7)

Abbreviations: ADD/ADHD, attention-deficit/hyperactivity disorder; max, maximum; min, minimum.

[a] All demographics provided are No. (%) unless otherwise specified.

METHODS

Participants

A total of 54 collegiate adapted athletes (26 males and 28 females) from 5 men's and 5 women's adapted athletics wheelchair basketball programs participated in the current study. Prior concussions were reported by 43% of the sample (n = 23), with 10 (43.5%) athletes reporting 1, 11 (47.8%) reporting 2, and 2 (8.7%) reporting 3 or more prior concussions (Table 1). Diagnosed modifiers ranged from 11.1% (migraines) to 24.1% (psychiatric disorder). Most participants had functional classifications ranging from 1.0 to 3.0/4.5.[19] A total of 23 different diagnosed pathologies were present in the sample, with 20 (37%) athletes diagnosed with spina bifida, 11 (20.4%) with SCI, 3 (5.6%) with CP, 2 (3.8%) with hereditary spastic paraplegia, and 1 (1.9% each) from each of the following: amputee (unilateral, bilateral, triple), bilateral femoral anteversion, chemotherapy-induced paralysis, Guillain-Barré syndrome, Klippel-Trenaunay syndrome, neurological knee injury, motor neuron disease, multiple sclerosis, muscular dystrophy, nerve damage (lower extremity), osteogenesis imperfecta, proximal femoral focal deficiency, sacral agenesis, tibial hemimelia, tighten spinal cord, and transverse myelitis. Of those with SCI, the following levels were present: L1/2, L2–5, L4, T3–7, T5, T6–8, T7 (n = 2), T9/10, T10 (n = 2), and T11. Full demographics of the sample are provided in Table 1. Exclusionary criteria consisted of any adapted athletes who did not use a wheelchair throughout the day for daily living. All participants were deemed healthy to compete in collegiate adapted athletics with no restrictions by a team physician or athletic trainer. Participants completed the study during designated research time slots while traveling to the host university for competition, tournaments, and championships during the spring 2023 season. Institutional review board approval was granted by the host institution, and informed consent was obtained before testing.

Measures

Adapted athletes completed the VOMS assessment in a quiet environment during designated times outside of practice and competition to negate any exercise effects on the VOMS.[20] The VOMS evaluates normal (pretest) ratings of headache, dizziness, nausea, and fogginess, followed by symptom provocation of each of those 4 symptoms, during a series of ocular (smooth pursuits, horizontal and vertical saccades, convergence) and head movement tasks (horizontal and vertical vestibular/ocular reflex [VOR/gaze stability] and visual motion sensitivity [VMS/VOR cancellation]).[11] All symptoms were self-rated from 0 (*none*) to 10 (*severe*), with higher scores indicating greater symptom provocation. All provocation scores were scored as a change from pretest administration symptoms.[20–22] For example, a pretest headache symptom score of a 1 and a post-VMS headache score of a 2 would result in a +1 score. Total VOMS task scores are reported as the sum of the 4 symptoms by task (eg, horizontal saccades).

Statistical Analysis

General descriptive (ie, means, SDs, frequencies) and inferential statistics were used to summarize all demographic information and VOMS symptoms. Due to nonparametric data and most asymptomatic performance, all medians of the VOMS were 0. Means and SDs are provided for ease of clinical utility and understanding by health care professionals. A series of Mann-Whitney U tests were conducted to determine differences between modifier groups of sex (male and female) and concussion history (prior history or no history). A Kruskal-Wallis H test was used for group differences by functional classification (1.0–1.5, 2.0–2.5, and 3.0–4.5). Vestibular/Ocular Motor Screening items were run separately by pretest, ocular, and vestibular symptoms to avoid statistical effects of multiple comparisons. To determine the internal consistency of VOMS performance, a series of Cronbach α tests were conducted. Separate α's were also provided for the mVOMS due to SCOAT6 implementation.

RESULTS

After an outlier analysis, 1 individual was flagged with outlying VOMS provocation. Therefore, a total sample of 53 participants' data was included. Approximately 50% (n = 27) reported zero symptom provocation throughout the VOMS, with approximately 72% having no pretest symptoms. The most provoking components of the VOMS were the VMS/VOR cancellation (41.5% provocation, n = 22) followed by both vertical VOR and horizontal saccades (24.5% provocation, n = 13) and horizonal VOR (22.6% provocation, n = 12), with provocation scores reaching 7, 6, and 6 out of 10, respectively (Table 2). Internal consistency was good for the VOMS ($\alpha = 0.863$) and mVOMS components only ($\alpha = 0.765$).

Sex Differences

No sex differences were observed in the pretest symptoms ($U = 338.5$, $P = .778$) of headache, dizziness, nausea, and fogginess. These findings extended to ocular-based (U range = 274.0–324.5, P range = .061–.303) and vestibular-based (U range = 337.5–348.5, P range = .750–.952) components (Table 3).

Table 2. VOMS Performance for the Sample[a]

VOMS Components	Mean ± SD	Range (Min–Max)	No. (%) Zero Scoring
Pretest symptoms total	0.72 ± 1.5	9 (0–9)	38 (71.6)
Headache	0.49 ± 0.9	4 (0–4)	40 (75.4)
Dizziness	0.13 ± 0.5	3 (0–3)	50 (94.3)
Nausea	0.06 ± 0.3	2 (0–2)	51 (96.2)
Fogginess	0.13 ± 0.4	2 (0–2)	48 (90.5)
Smooth pursuits	0.15 ± 0.6	4 (0–4)	49 (92.4)
Horizontal saccades	0.42 ± 0.8	3 (0–3)	40 (75.4)
Vertical saccades	0.32 ± 0.6	3 (0–3)	42 (79.2)
Convergence	0.21 ± 0.6	3 (0–3)	47 (88.6)
Horizontal VOR	0.51 ± 1.2	6 (0–6)	41 (77.3)
Vertical VOR	0.51 ± 1.1	6 (0–6)	40 (75.4)
VMS/VOR cancellation	0.87 ± 1.4	7 (0–7)	31 (58.5)

Abbreviations: Max, maximum; Min, minimum; VMS, visual motion sensitivity; VOMS, Vestibular/Ocular Motor Screening; VOR, vestibular/ocular reflex.

[a] Zero scoring indicates zero symptom provocation on the VOMS.

Prior Concussion History Differences

Adapted athletes with a history of prior concussion reported greater provocation on the horizontal saccades of the VOMS ($U = 233.5$, $P = .008$) than those with no history (Table 3). Evaluation of specific provoked symptoms on horizontal saccades revealed differences in dizziness ($U = 249.5$, $P = .019$) only, with no differences in headache ($U = 330.0$, $P = .253$), nausea ($U = 330.0$, $P = .253$), or fogginess ($U = 345.0$, $P = 1.000$). Further, horizontal saccades differences between prior concussion groups did not exist when compared with those with 1 and 2 or more concussions ($U = 55.5$, $P = .563$). No group differences were observed in pretest symptoms ($U = 296.0$, $P = .266$) or other ocular-based (U range = 268.5–308.5, P range = .060–.234) and vestibular-based (U range = 293.5–305.5, P range = .207–.347) components (Table 3).

Functional Classification Differences

Regarding functional classification, significant differences were noted between groups on horizontal saccades ($H = 9.2$, $P = .010$), horizontal ($H = 6.3$, $P = .043$) and vertical ($H = 6.0$, $P = .048$) VOR, and VMS/VOR cancellation ($H = 6.6$, $P = .036$; Table 3). Compared with 1.0–1.5 athletes, 2.0–2.5 athletes had greater provocation on horizontal saccades ($U = 95.0$, $P = .002$), horizontal ($U = 102.0$, $P = .009$) and vertical ($U = 111.0$, $P = .020$) VOR, and VMS ($U = 100.0$, $P = .022$). Greater symptom provocation was also observed in the 3.0–4.5 group when specifically compared with the 1.0–1.5 group on horizontal saccades ($U = 104.5$, $P = .005$), vertical VOR ($U = 112.0$, $P = .023$), and VMS ($U = 100.0$, $P = .022$). No functional classification differences occurred in pretest symptoms ($H = 1.1$, $P = .572$) or other ocular components (H range = 5.4–0.76, P range = .064–.681) on the VOMS.

DISCUSSION

The purpose of this study was to examine baseline performance and potential modifying factors of sex, history of concussion, and functional classification on the VOMS in a national sample of collegiate adapted athletes. Demographically, our sample was like a previous study in adapted wheelchair sport athletes based on pathologies. Specifically, Wessels et al included 42% SCI, 17% spina bifida, and 3% CP diagnoses,

Table 3. VOMS Performance by Modifier[a]

VOMS Components	Sex			Concussion History			Functional Classification			
	Male	Female	*P* Value	Prior Hx	No Hx	*P* Value	1.0 & 1.5	2.0 & 2.5	3.0–4.5	*P* Value
Pretest symptoms total	0.62 ± 1.0	0.81 ± 1.9	.778	1.09 ± 2.0	0.42 ± 0.8	.266	0.53 ± 0.9	1.24 ± 2.3	0.41 ± 0.8	.572
Headache	0.69 ± 1.1	0.30 ± 0.7	.224	0.65 ± 1.0	0.37 ± 0.9	.312	0.42 ± 0.9	0.47 ± 0.9	0.59 ± 1.1	.867
Dizziness	0.08 ± 0.4	0.19 ± 0.7	.564	0.22 ± 0.7	0.07 ± 0.3	.395	0.11 ± 0.4	0.29 ± 0.8	0.00 ± 0.0	.331
Nausea	0.00 ± 0.0	0.11 ± 0.4	.161	0.09 ± 0.4	0.03 ± 1.8	.828	0.00 ± 0.0	0.18 ± 0.5	0.00 ± 0.0	.116
Fogginess	0.04 ± 0.2	0.22 ± 0.5	.166	0.13 ± 0.4	0.13 ± 0.4	.887	0.05 ± 0.2	0.29 ± 0.6	0.06 ± 0.2	.341
Smooth pursuits	0.04 ± 0.2	0.26 ± 0.8	.303	0.30 ± 0.9	0.03 ± 0.2	.176	0.05 ± 0.2	0.35 ± 1.0	0.06 ± 0.2	.681
Horizontal saccades	0.27 ± 0.7	0.56 ± 0.9	.140	0.70 ± 0.9	0.20 ± 0.6	**.008**	0.00 ± 0.0	0.59 ± 0.8	0.71 ± 1.1	**.010**
Vertical saccades	0.15 ± 0.4	0.48 ± 0.8	.061	0.52 ± 0.8	0.17 ± 0.4	.060	0.05 ± 0.2	0.59 ± 0.9	0.35 ± 0.6	.064
Convergence	0.04 ± 0.2	0.37 ± 0.8	.086	0.30 ± 0.7	0.13 ± 0.5	.234	0.00 ± 0.0	0.35 ± 0.8	0.29 ± 0.7	.158
Horizontal VOR	0.42 ± 1.0	0.59 ± 1.4	.952	0.78 ± 1.5	0.30 ± 0.8	.207	0.05 ± 0.2	0.76 ± 1.2	0.76 ± 1.7	**.043**
Vertical VOR	0.42 ± 1.0	0.59 ± 1.3	.750	0.70 ± 1.4	0.37 ± 0.9	.347	0.05 ± 0.2	0.71 ± 1.1	0.82 ± 1.6	**.048**
VMS/VOR cancellation	0.69 ± 1.0	1.04 ± 1.7	.825	1.22 ± 1.8	0.60 ± 1.0	.266	0.21 ± 0.4	1.06 ± 1.3	1.41 ± 1.9	**.036**

Abbreviations: Hx, history; VMS, visual motion sensitivity; VOMS, Vestibular/Ocular Motor Screening; VOR, vestibular/ocular reflex.
[a] Bold values indicate statistical significance of $P \leq .05$.

which is comparable with the 37%, 20%, and 5%, respectively, in the current study.[23] Of those with SCI, 69% injured the thoracic spine and 18.5% injured the lumbar spine versus 75% and 25%, respectively, in our sample. This indicates that our sample may be largely reflective of the common pathologies that occur in adapted athletics. Our sample had a concussion history prevalence of 43%, which is 2.2 times higher than previous prevalence (19%) in college and national adapted wheelchair basketball athletes aged 18 to 60 years and nearly twice the prevalence (21%–25%) of college football athletes.[23–25] Given the previous studies' age range of up to 60 years, the prevalence of the current study is concerning, due to the shorter longitudinal time-window to sustain a concussion.[23] This may reflect a current epidemiological trend in adapted athletics with a rising rate of concussion at the collegiate level, especially compared with nonadapted college sports. However, longitudinal studies are needed to better understand concussion rates and risk in this sample. The prevalence of attention-deficit/hyperactivity disorder (ADD/ADHD) in the sample is like published rates (7%) in collegiate athletes, while our 13% prevalence of depression, anxiety, or psychiatric disorders is lower than findings in college athletes (anxiety, 12.5%; depression, 22%), especially given the suggested increases in mental health issues after the COVID-19 pandemic.[26–29] While we did not specify which psychiatric disorder our sample had, our overall prevalence may reflect the advancement of wellness resources available to college athletes.[30] Our sample had a 6% prevalence of diagnosed migraines, whereas the NCAA Headache Task Force has identified that upward of 24% of college athletes suffer from migraines, and 32% to 46% of them report a history of concussion.[31] It remains unclear whether the migraines and previous concussions are linked in the previous and current studies as well as other diagnosed comorbidities.

The values provided on the VOMS are like those from the CARE Consortium, with scores around 0.4 to 0.6, with VMS and VOR producing the greatest scores at baseline.[32] Sex was determined to not affect baseline VOMS symptom provocation in adapted athletes, which is supported by Moran et al, who noted similar findings in youth football and soccer athletes.[33] While sex has been identified to influence symptom reporting between males and females at the collegiate level, that is on larger symptom inventories and during nonprovoking eye and head movement tasks.[34,35] However, postinjury sex differences have been noted in 9- to 18-year-old concussed individuals on the VOR items only, which may provide early insight into adapted athlete performance postconcussion, but more data need to be examined in the adapted population.[36] Previous research into the effects of concussion history on the VOMS is scarce. To our knowledge, this is the first study to evaluate this topic, which revealed higher scores after horizontal saccades. It remains uncertain as to why these findings may have occurred, except for the potential for underlying and undiagnosed visual-spatial or oculomotor impairment, whether related to adapted pathologies or not. After SCI, corticospinal and vestibulospinal pathway transmission is impaired when using transcranial magnetic stimulation, which may have application to vestibular symptom provocation in those adapted athletes diagnosed with SCI.[37] The most notable findings on the VOMS in adapted athletes is that individuals in lower functional classifications (1.0–1.5) had significantly less provocation on horizontal saccades and all vestibular (VOR and VMS) components. The main assumption for this result is that athletes with functional classifications of 2.0–2.5 and 3.0–4.5 have increasing levels of function and trunk stability in which their vestibular systems are more developed to perform rapid eye and head movements, as compared with those at the lower classifications with little or no trunk movement, thus decreasing the need for stabilization and adjustments in the detection of linear and rotational head acceleration signals.[38] Despite low prevalence of CP in our sample ($n = 3$), children with CP have been noted to have worse velocity gain during horizontal smooth pursuit and VOR cancellation gain than children without CP.[39] With VOR cancellation being another name for VMS, our group difference findings between functional classifications may be supported by this evidence, as the 3 individuals diagnosed with CP in the current study had functional classifications of 1.0, 1.5, and 2.0. This may represent a relationship between neurologic-motor disability and vestibular pathways.

The VOMS was originally developed to serve as a brief clinical screening tool for vestibular and ocular motor impairments and symptoms after an SRC; however, initial data did not account for the change from pretest symptoms.[11] More recent evidence in concussed collegiate athletes noted change scores between 0.60 (smooth pursuits) and 2.76 (VMS) on the VOMS.[40] Our findings at baseline in adapted athletes remained below all mean change scores in the concussed college athletes sample, indicating that most adapted athlete samples should not report false-positive numbers. Additionally, we saw our least provocation in smooth pursuits and convergence and greatest provocation in VMS, followed by identical provocation in horizontal and vertical VOR, which mirror those in concussed collegiate athletes. It may then be speculated that our findings in adapted athletes may be like postinjury in collegiate athlete data, and therefore, including the VOMS with symptom severity scores on the SCAT6 symptom inventory would yield improved diagnostic utility postinjury.[41] A large component of the VOMS is the reporting of headache and dizziness symptoms during each of the individual vestibular and ocular tasks. In this study, we not only attempt to report mean values for an adapted athlete sample at baseline that can be utilized clinically by athletic trainers of collegiate adapted athletes and physicians in the absence of individual baseline assessment, but we also identify the potential vestibulo-ocular relationship with SCI in athletes. Interestingly, in nonathletic populations with SCI, similar symptoms from the VOMS have yielded risk factors for chronic symptoms; upward of 10% of adults with spina bifida and shunted hydrocephalus required pain management for chronic headaches, which makes evaluating and managing patients with spina bifida challenging.[42] With case potential for dizziness and autonomic dysfunction after traumatic SCI, separating SCI and SRC effects is also difficult.[43,44]

Due to advancements and the inclusion of additional assessment and recovery metrics in the SCAT6 and SCOAT6, these newly implemented items need to be studied in adapted and parasport athletes to understand normal performance and the influence of modifiers. These items consist of orthostatic vital signs, cervical spine assessment, and depression or anxiety screenings, potentially using the Sport Mental Health Assessment Tool (SMHAT-1).[45] Future researchers in adapted sports also need to address modifications for graded exercise, rehabilitation, and return to sport. This study was not without limitations. First, we did not include all adapted athletes, only those who use a day-chair outside of adapted sports. To better understand normative performance and performance by pathology, larger sample sizes are needed across pathologies. Given the low number of collegiate adapted programs, this may be challenging. We also had lower numbers of athletes with comorbidities of ADHD, migraines, and psychiatric disorders to appropriately compare those with and without those diagnoses. It is unclear what crossover effect these diagnoses may have had on concussion history (eg, prior concussions and ADHD). Our findings are also only applicable to baseline measures, for which postconcussion results may differ on the VOMS. It is unclear whether these findings extend to noncollegiate adapted sports, specifically lifespan para-athletes.

In conclusion, the VOMS appears to be a clinically useful tool in adapted athletes, but caution is needed in interpreting saccadic and VOR provocation, as higher symptom-provoking scores were noted in those with a prior concussion history and higher functional classification. Future research is needed to further expand on these findings at postinjury timelines and across specific pathologies.

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