Sex Differences on Vestibular and Ocular Motor Assessment in Youth Athletes

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Context: The Vestibular/Ocular Motor Screening (VOMS) is a newly developed measure that evaluates vestibular and ocular motor symptom provocation after sport-related concussion. The effects of sex on baseline VOMS scores in youth athletes have not been established.

Objective: To examine sex differences on baseline VOMS assessment among youth athletes.

Results: No sex differences were demonstrated between male and female youth athletes on individual VOMS items (P range = .07–.98). Female sex was not associated with increased odds for VOMS scores over clinical-cutoff levels

(range: odds ratio = 0.64; 95% confidence interval = 0.35, 1.15; P=.13; odds ratio = 0.91; 95% confidence interval = 0.48, 1.71; P=.77).

Conclusions: No sex differences were present on baseline VOMS scores in youth athletes, nor was sex a risk factor for an abnormal VOMS score. These findings highlight the need for continual baseline and postconcussion assessments using multifaceted assessment strategies.

Key Words: concussions, mild traumatic brain injuries, pediatrics

port-related concussion continues to be a growing concern, with an estimated 1.6 to 3.8 million injuries occurring annually in the United States,¹ a majority to children aged 5 to 18 years.² Concussion is associated with a myriad of physical, emotional, cognitive, and sleep-related symptoms and impairments that affect each athlete differently, which requires a multifaceted management approach.^{3,4} It has been suggested that nearly 40% of concussed individuals present with vestibular deficits,^{5–7} whereas 65% to 90% of individuals who have sustained a traumatic brain injury present with oculomotor dysfunction.8 The Vestibular/Ocular Motor Screening (VOMS) was developed as a screening tool to assess vestibular and ocular motor impairment after sportrelated concussion. The VOMS uses a series of symptomprovocation tests of the vestibular function domains of the vestibular-ocular reflex (VOR) and visual motion sensitivity (VMS), along with the ocular domains of pursuit, saccades, and convergence. Previous researchers9 suggested the VOMS could be clinically useful in differentiating individuals with concussions from healthy controls, given the high internal consistency ($\alpha = .92$) and moderate validity among concussed and healthy control athletes aged 9 to 18 years. Preliminary investigation of the VOMS showed the reliability and association of risk factors with abnormal VOMS results at baseline. Overall, at baseline, the VOMS displayed high consistency ($\alpha = .97$), and 11% of participants produced false-positive results of abnormal VOMS performance.¹⁰ Additionally, a history of motion sickness and female sex were reported as risk factors for 1 or more VOMS scores being above cutoff levels. To further understand the role of sex in VOMS performance, Sufrinko et al¹¹ examined sex differences on the VOMS after sport-related concussion in athletes aged 9 to 18 years. Females reported greater provocation of the horizontal VOR domain than males; no sex differences were noted for any other VOMS domain. Sex

differences on sport-related concussion assessments have been consistently reported,^{7,12–15} both at baseline and postinjury, but further investigation is needed to understand the influence of sex on the VOMS assessment in youth athletes between the ages of 8 and 14 years. It is possible that baseline sex differences on the VOMS may extend to youth athletes based on sex differences in cognitive-sensory symptoms at baseline in 13- to 18-year-old athletes.¹⁶ Similarly, collegiate females reported higher symptom scores than males for headache and nausea,¹⁴ which are symptoms assessed on the VOMS. As headache and nausea have been attributed to female athletes' menstrual cycles,¹⁴ it remains unknown whether these symptoms and their provocation on the VOMS would elicit similar trends.

Therefore, the primary purpose of our study was to examine sex differences in baseline VOMS assessment among youth athletes. A secondary purpose was to identify any sex differences at baseline associated with falsepositive and VOMS scores above clinical-cutoff levels.

METHODS

Participants and Procedures

A total of 423 youth athletes, aged 8 to 14 years, from youth football and soccer organizations participated in the study. Athletes were recruited from an ongoing youth concussion-surveillance program. Institutional review board approval was obtained before the research began, along with parental consent and child assent.

The VOMS baseline assessments were completed before the athletes' respective sport seasons, with trained research staff and athletic trainers administering the assessments to all participants in a standardized fashion. Parents of participants provided their child's sex and medical history via a demographic questionnaire.

 Table 1.
 Comparison of Baseline Vestibular/Ocular Motor

 Screening Domain Scores Between Male and Female Youth
 Athletes

| | Mean | | |
|-------------------------------------|----------------|----------------|----------------------|
| Domain | Males | Females | P Value ^a |
| Smooth pursuit | 0.50 ± 1.8 | 0.46 ± 1.2 | .32 |
| Horizontal saccade | 0.53 ± 1.5 | 0.60 ± 1.7 | .98 |
| Vertical saccade | 0.58 ± 1.8 | $0.66~\pm~1.8$ | .50 |
| Convergence | 0.55 ± 1.9 | 0.71 ± 2.5 | .80 |
| Near point of convergence | | | |
| distance, cm | 1.52 ± 2.7 | 1.45 ± 2.4 | .71 |
| Horizontal vestibular-ocular reflex | 0.72 ± 1.9 | $0.66~\pm~1.9$ | .33 |
| Vertical vestibular-ocular reflex | 0.66 ± 2.0 | 0.58 ± 1.4 | .21 |
| Visual motion sensitivity | 0.61 ± 2.0 | 0.90 ± 2.4 | .07 |

^a Mann-Whitney U nonparametric test.

Eligibility Criteria

Inclusion criteria were any athletes aged 8 to 14 years who were currently enrolled in one of the participating youth programs. Individuals were excluded from the study if they were diagnosed with a concussion in the past 6 months or had any history of brain surgery or intracranial condition as determined by abnormal computed tomography or magnetic resonance imaging.

Outcome Measures

The VOMS is a brief screening tool that assesses vestibular and ocular motor impairments via patient-reported symptom provocation. The VOMS consists of smooth pursuits, horizontal and vertical saccades, near point of convergence (NPC), and horizontal and vertical VOR and VMS. Patients rate their symptoms of headache, dizziness, nausea, and fogginess on a scale of 0 (none) to 10 (severe) before beginning the VOMS assessment. After completing each component, patients report their current symptoms for their VOMS symptom-provocation scores. In addition to symptom provocation, NPC distance is measured objectively, using the average distance (cm) across 3 trials. The total symptom-provocation scores were tallied for each VOMS item and analyzed. The VOMS takes approximately 3 to 5 minutes to complete and can be administered by a physician, athletic trainer, or other health care professional.

Statistical Analysis

We used a series of Mann-Whitney U tests to compare male and female scores for each VOMS domain. A series of univariate nonparametric tests (χ^2 with odds ratios [ORs] and 95% confidence intervals [CIs]) were used to examine the association of sex and VOMS clinical-cutoff scores. The clinical cutoff for the VOMS was a score of 2 or more for any individual VOMS symptom-provocation item or \geq 5 cm average NPC distance. These clinical cutoffs demonstrated 38% and 50% increases, respectively, in the probability of correctly identifying patients with concussions.⁹

RESULTS

A total of 423 youth athletes (age = 11.0 ± 1.5 years) participated in the study. The sample consisted of 278 (65.7%) males and 145 (34.3%) females. Of the

Table 2. Youth Athletes with Abnormal Vestibular/Ocular Motor Screening Domain Scores by Sex, No. (%)

| Domain | $\begin{array}{l} \text{Males} \\ \text{(n}=\text{278)} \end{array}$ | Females $(n = 145)$ |
|--|--|---------------------|
| Smooth pursuit | 10.0 (28) | 8.9 (13) |
| Horizontal saccade | 10.8 (30) | 11.7 (17) |
| Vertical saccade | 9.3 (26) | 12.4 (18) |
| Convergence | 10.0 (28) | 11.7 (17) |
| Near point of convergence distance, cm | 9.7 (27) | 11.0 (16) |
| Horizontal vestibular-ocular reflex | 12.9 (36) | 14.4 (21) |
| Vertical vestibular-ocular reflex | 11.8 (33) | 13.7 (20) |
| Visual motion sensitivity | 10.8 (30) | 15.8 (23) |

participants, 160 (37.8%) were youth football athletes, whereas 263 (62.2%) were youth soccer athletes. Additionally, 38 athletes (9.0%) were diagnosed with a history of concussion, 28 (6.6%) with migraines, and 30 (7.0%) with attention or learning disabilities (or both); 20 (4.7%) reported using medication for their diagnosed disability.

The Mann-Whitney U test did not reveal any differences between male and female youth athletes for any VOMS domain (P range = .07-.98; Table 1). No differences were noted between sexes for NPC distance (P = .71).

When examining individual VOMS domains, we found that 9% to 13% of males had domain scores higher than the clinical-cutoff levels, compared with 9% to 16% of females (Table 2). In addition, the χ^2 statistic and ORs revealed no increased likelihood of scoring greater than clinical-cutoff levels due to sex (Table 3).

DISCUSSION

This current study is the first, to our knowledge, to examine sex differences on the VOMS baseline assessment in youth athletes. We did not find sex differences for any of the VOMS domains among youth athletes. In addition, no sex differences were present in the clinicalcutoff scores on the VOMS concussion assessment at baseline, despite 9% to 13% of males and 9% to 16% of females scoring higher than clinical-cutoff levels. These results contrast with those of previous researchers¹⁰ who reported female sex as a risk factor for VOMS scores greater than clinical-cutoff levels in healthy collegiate athletes. However, sex was not associated with increased odds of demonstrating an abnormal NPC distance, which is consistent with our findings. It is possible that the

| Table 3. | Odds Ratios for Abnormal Vestibular/Ocular Motor |
|-----------|--|
| Screening | g Domain Scores by Sex Among Youth Athletes |

| Domain | P Value | Odds Ratio (95% Confidence Interval) |
|-------------------------------------|---------|--|
| Smooth pursuit | .71 | 1.13 (0.57, 2.26) |
| Horizontal saccade | .77 | 0.91 (0.48, 1.71) |
| Vertical saccade | .32 | 0.72 (0.38, 1.37) |
| Convergence | .60 | 0.84 (0.44, 1.59) |
| Near point of convergence | | |
| distance, cm | .66 | 0.86 (0.45, 1.66) |
| Horizontal vestibular-ocular reflex | .66 | 0.87 (0.49, 1.56) |
| Vertical vestibular-ocular reflex | .57 | 0.84 (0.46, 1.52) |
| Visual motion sensitivity | .13 | 0.64 (0.35, 1.15) |

results differed due to reporting sex as a risk factor for each VOMS subscale rather than identifying risk factors that predicted more than 1 VOMS domain score would be higher than the clinical-cutoff level. Our results also differed from those of Sufrinko et al,¹¹ who reported sex differences, specifically higher mean VOMS scores on the horizontal VOR domain in adolescent females after sportrelated concussion. Sex differences did not extend to the VOMS domains other than horizontal VOR, which is consistent with our findings for the VOMS domains. These differences may reflect the fact that we examined only baseline sex differences and Sufrinko et al¹¹ reported sex differences postconcussion.

Although some investigators¹⁷ have suggested that sex differences do not occur on baseline concussion assessment, others have noted greater symptom reporting by female athletes at baseline,^{7,13,14} especially in the youth population.¹⁶ At baseline, females described greater cognitive-sensory (eg, sensitivity to light or noise, difficulty concentrating), fatigue, and emotional disturbance symptoms.¹⁴ Females may be more likely to report vestibular-somatic (eg, headache, dizziness) symptoms,⁷ yet these may be attributed to a female athlete's menstrual cycle¹⁴; this may not have been a factor in our study due to the growth and maturation phases of younger female athletes 8 to 14 years of age. Further investigation of clinical assessment tools is needed to confirm the level of growth and maturation, including sex differences.

Previous authors⁹ determined that, compared with other VOMS domains, the VOR was best at distinguishing athletes with concussions from controls. Interestingly, we observed that horizontal VOR had the highest and second highest mean provocation scores among males and females, respectively. Additionally, the VMS domains demonstrated the second-best odds of identifying patients with concussions⁹; the highest mean VOMS scores were for females, along with the closest risk for abnormal scores over clinical-cutoff levels. Females may be more likely to follow a vestibular trajectory, due to vestibular impairment and symptoms, which could provide insight into the higher mean score on the VMS for the females in our study, as well as sex differences on the VOR among collegiate females.^{11,18} Although these results did not display the statistical significance seen among older athletes, special consideration may be warranted for athletic trainers, physicians, and other health care professionals who use the VOMS to assess patients with sport-related concussion. The results show a trend similar to that of previous data, but this clinical utility warrants further investigation of the role of sex on postconcussion VOMS assessment and potential sex differences in youth athletes.

Females reported more headache and dizziness symptoms, possibly related to their menstrual cycles,¹⁴ yet we do not know how many female athletes in the current sample had begun menstruation, along with the hormonal development and changes that may lead to higher VOMS scores in the later years of adolescence. Individuals were not prescreened for underlying vestibular dysfunction or conditions, nor were they excluded or screened for neurologic or visual disorders. Another limitation and a possible explanation for the results may be attributed to the current sample having a 2:1 male-to-female ratio. Future

researchers should aim to correct these concerns and investigate male and female athletes at later adolescent ages and in early adulthood to determine when sex differences may occur during maturation and development. Future authors should also continue to examine both baseline and postconcussion assessments using the VOMS and address other risk factors for abnormal VOMS outcomes.

CONCLUSIONS

Our findings indicate that sex differences did not occur on the VOMS at baseline in youth football and soccer athletes. In addition, sex was not a risk factor for increased odds of reporting scores that were greater than clinical cutoffs for any VOMS domain. Our results highlight the need to continually evaluate baseline performance as it relates to sport-related concussion and the importance of multifaceted assessment strategies. Moving forward, investigators should continue to examine both baseline and postconcussion performance on the VOMS, while addressing the importance of special consideration for female athletes throughout adolescence.

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