A Positive Vestibular/Ocular Motor Screening (VOMS) Is Associated With Increased Recovery Time After Sports-Related Concussion in Youth and Adolescent Athletes

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A Positive Vestibular/Ocular Motor Screening (VOMS) Is Associated With Increased Recovery Time After Sports-Related Concussion in Youth and Adolescent Athletes

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Background: Vestibular and ocular motor impairments are routinely reported in patients with sports-related concussion (SRC) and may result in delayed return to play (RTP). The Vestibular/Ocular Motor Screening (VOMS) assessment has been shown to be consistent and sensitive in identifying concussion when used as part of a comprehensive examination. To what extent these impairments or symptoms are associated with length of recovery is unknown.

Purpose: To examine whether symptom provocation or clinical abnormality in specific domains of the VOMS results in protracted recovery (time from SRC to commencement of RTP protocol).

Study Design: Cohort study (prognosis); Level of evidence, 2.

Methods: A retrospective chart review was conducted of 167 patients (69 girls, 98 boys; mean $\pm$ SD age, 15 $\pm$ 2 years [range, 11-19 years]) presenting with SRC in 2014. During the initial visit, VOMS was performed in which symptom provocation or clinical abnormality (eg, unsmooth eye movements) was documented by use of a dichotomous scale (0 = not present, 1 = present). The VOMS used in this clinic consisted of smooth pursuits (SMO_PUR), horizontal and vertical saccades (HOR_SAC and VER_SAC), horizontal and vertical vestibular ocular reflex (HOR_VOR and VER_VOR), near point of convergence (NPC), and accommodation (ACCOM). Domains were also categorized into ocular motor (SMO_PUR, HOR_SAC, VER_SAC, NPC, ACCOM) and vestibular (HOR_VOR, VER_VOR). Cox proportional hazard models were used to explore the relationship between the domains and recovery. Alpha was set at $P \leq .05$.

Results: Symptom provocation and/or clinical abnormality in all domains except NPC (P = .107) and ACCOM (P = .234) delayed recovery (domain, hazard ratio [95% CI]: SMO_PUR, 0.65 [0.47-0.90], P = .009; HOR_SAC, 0.68 [0.50-0.94], P = .018; VER_SAC, 0.55 [0.40-0.75], $P < .001$; HOR_VOR, 0.68 [0.49-0.94], P = .018; VER_VOR, 0.60 [0.44-0.83], P = .002). The lowest crude hazard ratio was for ocular motor category (0.45 [0.32-0.63], $P < .001$).

Conclusion: These data suggest that symptom provocation/clinical abnormality associated with all domains except NPC and ACCOM can delay recovery after SRC in youth and adolescents. Thus, the VOMS not only may augment current diagnostic tools but also may serve as a predictor of recovery time in patients with SRC. The findings of this study may lead to more effective prognosis of concussion in youth and adolescents.

Keywords: concussion; vestibular; ocular motor; symptoms

The consensus definition of concussion established at the 4th International Conference on Concussion in Sport in 2012 describes concussion as a "complex process affecting the brain."[26] The acute signs and symptoms associated with concussion vary but may include immediate loss of consciousness, headache, amnesia, dizziness, impaired postural control, ophthalmic dysfunction, and cognitive dysfunction.[7,18,26] The US Centers for Disease Control and

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Prevention estimate that 1.7 million traumatic brain injuries (TBIs) occur annually,[14] with approximately 300,000 of those injuries classified as sports-related concussion (SRC).[15] In the United States it is estimated that 44 million children and adolescents participate in organized sport. A recent investigation of high school sports found that SRC represented 13.2% (n = 1936) of all athletic injuries that occurred during the 2008-2010 academic years.[23] Additional reports have estimated that 30% of concussions in 5- to 19-year-olds are sports related.[4,27] However, those values may not be all-encompassing because the general consensus is that roughly 53% of SRCs go unreported to the appropriate medical professionals.[12] The American Medical Society for Sports Medicine, in a recent position statement, suggested that protective equipment does not reduce the incidence and/or severity of concussion in sport,[18] highlighting the need for effective diagnosis and management of SRC.

Recently, it has been reported that vestibular and ocular motor dysfunction accompanies SRC.[28] Dizziness, a symptom associated with vestibular dysfunction, is reported in more than 50% of concussed athletes,[21] and dizziness at the time of injury has been reported to be more strongly associated with protracted recovery (>21 days) than any other clinical symptom.[22] In addition to dizziness, vision impairments are concurrently reported in concussed athletes.[19] Similar symptoms (eg, abnormal eye movements, visual instability, impaired postural control, dizziness, and headaches) are associated with disruption of both the vestibular and ocular motor systems and are frequently reported after concussive injury.[19] Concussed patients often have atypical clinical assessments of saccades, pursuit, near point of convergence (NPC), accommodation, and the vestibular ocular reflex (VOR).[34] Research demonstrates that collegiate and professional athletes tend to recover from SRC in approximately 1 week.[8,25] However, a number of investigations have found that youth and adolescents often require a protracted period of recovery.[3,5,16] Given that vestibular and ocular motor system impairments are often reported in patients with protracted recovery, it is important that clinicians be equipped with a valid and reliable screening tool to detect vestibular and ocular motor dysfunction, especially in a pediatric population.

Conventional tools for diagnosis and management of a concussive injury include physical and neurological examinations, neurocognitive testing, and sideline inventories such as the Sport Concussion Assessment Tool–3 (SCAT3) and Child SCAT3.[26] Valid instruments that uniquely assess vestibular and/or ocular motor function do exist (eg, the Balance Error Scoring System [BESS] and King-Devick Test)[17,20]; however, those tests do not sufficiently evaluate the complexity or synergy of the vestibular and ocular motor systems,[28] which are accountable for sensing motion of the head, maintenance of visual stability, balance, and vision.[32] Recently, a comprehensive assessment of the vestibular and ocular motor system was established. The Vestibular/Ocular Motor Screening (VOMS) was initially developed, assessed for internal consistency, and validated at the University of Pittsburgh Medical Center.[28] The VOMS is a clinical appraisal of the vestibular and ocular motor systems that evaluates smooth-pursuit eye movements, saccadic eye movements, NPC, the VOR, and visual motion sensitivity. Preliminary reports indicate that the VOMS accurately differentiates between athletes with SRC and healthy controls.[28] However, the relationship between vestibular and ocular motor impairments and symptoms, as identified by the VOMS, and recovery time after SRC is unknown. Thus, the purpose of the current study was to examine the relationship between symptom provocation/clinical abnormality from each VOMS domain and the time from concussive incident to commencement of the graduated return to play (RTP) protocol.

METHODS

Data and Participants

A retrospective, cross-sectional investigation was conducted via chart review to evaluate those patients treated for SRC from January 2014 to December 2014. This study was approved by the institutional review board. Given that the nature of this study was retrospective and that the risk posed to privacy was no more than minimal, the institutional review board granted full waiver of consent.

Initial chart review was conducted for 275 patients who presented to the clinic with a concussion from January 2014 to December 2014. Only those patients with a diagnosed SRC, between the ages of 11 to 20 years, who were assessed within 14 days of the initial date of injury were included in the analyses. Data were recorded from a total of 167 patients and included patient age at the time of concussion, sex, mechanism of injury, date of injury, date of initial evaluation, previous concussion, VOMS at first appointment, and date patient was cleared to begin the graduated RTP protocol. Patients with a history of any the following were excluded from this study: vestibular and/or ocular motor pathologic condition; brain surgery; ophthalmic surgery; neurological, cognitive, or behavioral disorders; or TBI graded more severe than concussion.

Measures

The Vestibular/Ocular Motor Screening. Adapted from an earlier version of instrumentation previously described,[28]

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the VOMS used at this clinic and reported in this study included brief assessments in the following domains: smooth pursuits, horizontal and vertical saccades, horizontal and vertical VOR, NPC, and accommodation. The domain visual motion sensitivity was excluded from this report because it was measured inconsistently and was dependent on severity of symptoms identified in the patient. During each evaluation, a trained clinician administered the VOMS in an examination room. Symptom provocation/clinical abnormality was reported dichotomously by a clinician (0 = no; 1 = yes) following evaluation of each domain for purposes of statistical analyses. Symptoms included but were not limited to headache, dizziness, nausea, and fogginess. Abnormal clinical findings included NPC larger than 6 cm, abnormal smooth pursuits, or abnormal saccadic eye movements. A video of the VOMS with accompanying instructions is available in the online version of this article.

Determination of Recovery Time. A patient was cleared to begin the graduated RTP protocol after he or she had remained symptom free for a minimum of 48 hours, displayed a normal physical examination, exhibited a normal VOMS, and achieved neurocognitive testing scores that were at the patient's baseline or within normal limits. The number of days from the date of the initial injury to beginning of the graduated RTP protocol was considered the recovery time and was used for statistical analyses.

Statistical Analyses

Both univariate and multivariate Cox proportional hazard models were used to explore the relationship between each of the 7 domains of the VOMS used in the clinic (smooth pursuits, horizontal and vertical saccades, horizontal and vertical VOR, NPC, and accommodation) and the time from concussive incident to clearance to begin graduated RTP protocol. In addition, we later categorized those domains attributed to ocular motor (smooth pursuits, horizontal and vertical saccades, NPC, and accommodation) and vestibular (horizontal and vertical VOR) assessments. The proportional hazards assumption necessary for the Cox proportional hazard model was tested by analyzing the significance of the interaction of time with each of the 7 domains. This assumption was supported. The results for the multivariate Cox proportional hazard model are also adjusted for sex. All P values are reported for 2-sided tests. SAS 9.4 was used to perform all analyses in this study.

RESULTS

Patients ranged in age from 11 to 19 years (mean ± SD, 15 ± 2 years). The sample included more boys (58.7%; n = 98) than girls (41.3%; n = 69). Approximately thirty percent (29.9%; n = 50) had experienced prior concussion. The overall recovery time was 19.9 ± 12.8 days and did not differ between those with previous concussion (20.3 ± 11.2 days) and those without (19.7 ± 13.4 days; P = .79). The time from concussive incident to graduated RTP protocol was significantly shorter for boys than for girls (boys, 16.9 ± 9.0 days; girls, 24.1 ± 15.9 days; P = .001).[33]

TABLE 1
Distribution of Patients Reporting Symptom Provocation With 1 or More VOMS Domains and Corresponding Recovery Time

VOMS Domain	n (%)	Recovery Time, d[a]
Smooth pursuits	61 (36.8)	23.2 ± 12.3
Horizontal saccades	81 (48.5)	22.9 ± 12.3
Vertical saccades	89 (53.6)	23.4 ± 13.9
Horizontal vestibular ocular reflex	65 (40.0)	22.3 ± 10.4
Vertical vestibular ocular reflex	73 (45.3)	23.0 ± 12.9
Near point of convergence	28 (16.8)	26.0 ± 14.9
Accommodation	39 (23.4)	23.2 ± 11.5

[a]Recovery time (mean ± SD) was calculated as time from concussive incident to clearance to initiate return-to-play protocol. VOMS, Vestibular/Ocular Motor Screening.

Patients presenting without symptom provocation or clinical abnormality (n = 54; 32.3%) returned to graduated RTP protocol faster (13.4 ± 8.2 days) than those presenting with symptom provocation on at least 1 VOMS domain (23.0 ± 13.4 days; $P < .001$). A positive correlation (r = 0.31; $P < .001$) was noted between the number of positive domains exhibited by the patients at the time of examination and recovery. All patients returned to play; thus, there were no censored data. The most common sports for which patients reported participation were basketball (11.4%; n = 19), football (42.5%; n = 71), and soccer (19.2%; n = 32). Other sports were lower in number and made up 27% (n = 45) of the total patient population. A distribution of patients presenting with symptom provocation/clinical abnormality within at least 1 VOMS domain is provided in Table 1. When VOMS domains were categorized into ocular motor or vestibular, a slightly larger proportion of patients reported symptom provocation from those domains attributed to ocular motor assessments (65.3%; n = 109) compared with those categorized as vestibular assessments (55.1%; n = 92). The results from the univariate Cox proportional hazards model are presented in Table 2. These data suggest that symptom provocation resulting from all domains associated with the VOMS, except NPC and accommodation, delays recovery. However, examination of the multivariate Cox proportional hazards model reveals the likelihood of a confounding variable and/or multicollinearity, because the number of significant crude hazard ratios decreases in the presence of controlling for other domains. An interesting finding is that a person with a concussion who has an ocular motor impairment has a significant hazard ratio value of approximately 0.45 regardless of whether we control for the other VOMS domains and sex. This was the lowest hazard ratio.

DISCUSSION

The purpose of the current study was to examine the relationship between symptom provocation/clinical abnormality from each VOMS domain and time from concussive incident to initiation of the graduated RTP protocol. The main finding was that symptom provocation/clinical

TABLE 2
Univariate and Multivariate Cox Regression Proportional Hazards Models for VOMS Domains[a]

VOMS Domain	Univariate HR[b] (95% CI)	*P*	Multivariate HR (95% CI)	*P*	Multivariate HR[c] (95% CI)	*P*
Smooth pursuits	0.65 (0.47-0.90)	.009	0.98 (0.64-1.52)	.938	0.96 (0.62-1.51)	.875
Horizontal saccades	0.68 (0.50-0.94)	.018	1.24 (0.71-2.17)	.454	1.19 (0.68-2.11)	.538
Vertical saccades	0.55 (0.40-0.75)	<.001	0.84 (0.47-1.50)	.556	0.92 (0.52-1.64)	.781
Horizontal VOR	0.68 (0.49-0.94)	.018	0.84 (0.48-1.48)	.551	0.78 (0.44-1.38)	.393
Vertical VOR	0.60 (0.44-0.83)	.002	0.89 (0.50-1.58)	.688	0.97 (0.55-1.72)	.913
Near point of convergence	0.70 (0.46-1.08)	.107	0.79 (0.43-1.43)	.427	0.78 (0.42-1.42)	.409
Accommodation	0.79 (0.55-1.16)	.234	1.29 (0.75-2.22)	.35	1.32 (0.47-2.53)	.333
Vestibular	0.55 (0.40-0.76)	<.001	1.09 (0.47-2.52)	.849	1.09 (0.47-2.53)	.842
Ocular motor	0.45 (0.32-0.63)	<.001	0.47 (0.23-0.97)	.042	0.44 (0.21-0.88)	.021

[a]The domains attributed to ocular motor assessments are smooth pursuits, horizontal and vertical saccades, near point of convergence, and accommodation. The domains attributed to vestibular assessments are horizontal and vertical VOR. HR, hazard ratio; VOMS, Vestibular/Ocular Motor Screening; VOR, vestibular ocular reflex.
[b]Crude HR.
[c]Adjusted for sex.

abnormality following all VOMS domains, excluding NPC and accommodation, is associated with an increased recovery time after SRC in youth and adolescent athletes.

Research has not been able to identify which, if any, clinical measures of concussion lead to a protracted recovery in children and adolescents.[35] While the VOMS is consistent and sensitive in identifying concussion,[28] to what extent vestibular or ocular motor impairments affect recovery time is largely unknown. Thus, the present study is the first to examine whether symptom provocation/clinical abnormality in specific domains of the VOMS results in extended recovery time after SRC in youth and adolescents. Ellis et al[13] recently reported that a large percentage (63%) of pediatric (aged $\leq$19 years) SRC patients with postconcussion syndrome (ie, recovery time >30 days) met the criteria for vestibulo-ocular dysfunction (VOD). Identification of VOD in that study used both clinical examination findings and results from a self-reported postconcussion symptom scale (PCSS). However, the explicit clinical abnormality and/or symptom associated with the injury and subsequent protracted recovery was not expounded. Further, although reported, the determination of VOD in that study has not been standardized or fully validated.

In the current study, the lowest crude hazard ratio, associated with the longest recovery time, was observed in those patients presenting with clinical abnormality or symptom related to vertical saccades and vertical VOR. Saccadic eye movement, a component of the ocular motor system, functions to focus images in the visual field onto the fovea centralis. In contrast, the VOR, under the control of the vestibular system, acts to stabilize images onto the retina while the head is moving. The neuroanatomic mechanism that facilitates the synergy of vestibular and ocular motor function consists of a complex network of sensory organs and processing areas that interact with the multiple components of the brain and spinal cord.[32] Thus, the precise mechanisms by which VOMS abnormalities arise after head trauma remain unclear. Physical examination via tools such as the VOMS may offer insight into the extent of the injury, but it remains relatively unknown whether the clinical abnormalities are a result of injury at the neuronal level (eg, excitotoxicity and cytoskeletal degradation) or at the structural level. While the current data suggest that those patients presenting with clinical abnormality or symptoms related to vertical saccades and vertical VOR may require a more conservative approach to recovery, future research is warranted to classify specific abnormalities of the vestibular and ocular motor systems and to identify the underlying mechanism of such injuries. Still, the brief and simple nature of the VOMS used in this study makes it an effective and attractive option for the diagnosis of SRC and assessment of vestibular and ocular motor dysfunction.

Research demonstrates a high occurrence of vision abnormalities (ie, accommodative disorders, convergence insufficiency, and saccadic dysfunction) associated with adolescent concussions.[24] Furthermore, previous literature has suggested that convergence insufficiency provokes concussion-related symptoms (ie, headache, difficulty focusing, blurred vision)[31] and is common in young athletes with greater neurocognitive impairment.[30] Pearce et al[30] reported that patients with convergence insufficiency have higher PCSS total scores than those without convergence insufficiency, leading those authors to suggest that convergence insufficiency may simply be an indicator of more severe injury. Nonetheless, convergence insufficiency is reported to be present in up to 46% of patients with mild traumatic brain injury and concussion.[2,6,9,10,28,30] In contrast, only 16.8% (28 of 167) of subjects in the current study presented with convergence insufficiency; however, those with convergence insufficiency did tend to have slower recoveries (26.0 ± 14.9 days). Despite the slower recoveries observed in those with convergence insufficiency, the fact that the crude hazard ratio associated with NPC approached 1 but was not significant suggests that assessing domains individually may not prove useful in predicting a protracted recovery. When domains were grouped as ocular motor or vestibular, abnormality within the ocular motor domain, which included NPC and accommodation, resulted in the lowest crude hazard ratio compared with individual domains. Taken together, these data support the utility of the VOMS as a whole and do not support assessment of individual domains exclusively for prognosis.

Clinical Implications

Although it is well documented that injury presentation and trajectory vary from patient to patient, targeted management of SRC is not common.[11] Current recommendations state that cognitive and physical rest forms the foundation of acute SRC management.[26] Although the medical community generally accepts those guidelines, the amount of rest recommended after SRC is not widely agreed upon, and few studies have examined the precise effect of cognitive and physical rest as it relates to recovery time. Furthermore, limited research has examined alternative SRC management strategies. Identification of specific vestibular/ocular motor abnormalities and their associated prognosis using the VOMS may aid clinicians in SRC management. Targeted vestibular/ocular motor rehabilitation has been examined in the context of concussion management. Although vestibular and ocular motor rehabilitation is not widely used, early research supports the use of such rehabilitation after concussion.[1,29] As an example, customized vestibular rehabilitation has proven to successfully reduce dizziness and improve balance after concussion in both youth and adults.[1] Still, further studies that examine targeted rehabilitation after SRC are warranted.

Limitations

The findings from this study are not without limitations. Data from the current study were collected in a retrospective manner, and thus complete data were not available for all patients. Further, a lack of baseline VOMS measurements prohibits us from knowing whether abnormalities associated with the VOMS were indeed a result of the SRC. Rapid recovery may also have reduced the number of positive symptoms and abnormalities observed in the current study, although all patients were seen within 14 days of injury (5.7 ± 3.5 days) in agreement with Mucha et al.[28] Further study is warranted in which VOMS is used as a sideline evaluation tool immediately after injury. The results presented herein are limited to youth and adolescent athletes (ages 11-19), a greater percentage of whom were male, and thus may not be indicative of the pattern associated with adult athletes. The anatomic and physiologic characteristics of vestibular and ocular motor dysfunction are elaborate, and clinicians using similar screening tools must be aware of the numerous neurological disorders that present with vestibular or ocular motor dysfunction.[32] While all patients with known underlying vestibular and ocular motor pathologic disorders were excluded from analysis, future research should aim to acquire serial VOMS results from young athletes and longitudinally examine developmental changes and results in the event that SRC occurs.

CONCLUSION

The results of this research suggest that symptom provocation and clinical abnormality within all domains of the VOMS, except for NPC and accommodation, delay recovery after SRC in youth and adolescents. Thus, the VOMS not only augments current diagnostic tools but also can predict a protracted recovery in young patients with SRC. Early identification of VOMS abnormalities after SRC may lead to advanced use of targeted rehabilitation, which may enhance the prognosis of recovery for patients who sustain SRC.

A Video Supplement for this article is available in the online version or at http://ajsm.sagepub.com/supplemental.

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