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ORIGINAL ARTICLE

The effects of sleep disturbance and chronotype on baseline vestibular/ocular motor screening in collegiate athletes

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ABSTRACT

Background: The vestibular/ocular motor screening (VOMS) is a clinically validated screening tool for concussion management. Multiple factors have been known to influence VOMS performance such as preexisting migraine and mood disorders. Poor sleep is an another important variable that warrants investigation as a modifier on the VOMS that may need to be considered during administration.
Aim: This study aims to examine whether self-reported sleep difficulties significantly modify baseline VOMS symptom provocation in collegiate athletes.
Methods: A total of 191 collegiate student-athletes completed a pre-season baseline VOMS and the 16-item Athlete Sleep Screening Questionnaire (ASSQ) before the start of their respective sport season. The ASSQ was used to establish sleep health variables consisting of hours of sleep per night, sleep difficulties when traveling for sport, chronotype (e.g., morning or evening person), and a sleep disturbance score (SDS) category of none, mild, and moderate + severe.
Results: Those who reported sleep disturbances when traveling for sport on that respective ASSQ item had higher pre-test VOMS symptoms ($P < 0.001$) and symptom provocation on convergence ($P = 0.015$), horizontal vestibular ocular reflex (VOR) ($P = 0.008$), and vertical VOR ($P = 0.039$). There were worse pre-test symptoms ($P = 0.015$) and provocation on horizontal VOR ($P = 0.046$) in the moderate + severe SDS group than no SDS. The moderate + severe SDS group reported worse symptom provocation on the horizontal ($P = 0.018$) and vertical VOR ($P = 0.010$), and VMS ($P = 0.017$). No differences were found on VOMS symptom provocation for hours of sleep or chronotype.
Conclusions: These results show agreement with previous symptom and neurocognitive data in that sleep difficulties among collegiate athletes may have an important role in the interpretation of baseline concussion testing. It may be beneficial to utilize sleep assessments with baseline concussion testing when using the VOMS as the clinical concussion measurement modality.
Relevance for Patients: The addition of sleep assessment may aid sports medicine practitioners in properly interpreting baseline VOMS scores. Pre-season baseline testing may need to be delayed if athletes report with poor sleep in the acute period prior.

1. Introduction

Recent research has demonstrated poor sleep among college student-athletes in the United States [1]. Researchers have identified that poor sleep may be related to negative health outcomes for athletes, such as depression, anxiety, and bodily pain [2]. Furthermore, many professionals in the field agree that an individual approach to aiding student-athletes in sleep behavior is recommended [3]. This may include an individualized method to baseline concussion testing for each student-athlete, based on sleep habits. Walsh *et al.* [3] further claimed that adolescent athletes may classify as more of an evening chronotype, with Bender *et al.* claiming that athletes may be more of a morning chronotype [4]. It is

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recommended that early morning or late-night training schedules be avoided to allow for proper sleep and recovery [3]. Lim *et al.* reported that elite athletes who were an evening chronotype had worse performance compared to those who were a morning chronotype [5]. It is possible that examining chronotype could be a salient factor in determining proper concussion baseline testing methods. Mihalik *et al.* [6] also suggested that sleep deprived athletes should not engage in baseline concussion testing until they experience a normal night of sleep. More specifically, given the importance of proper concussion management in sport, the relationship of baseline concussion testing and sleep habits in college student-athletes is a particularly important relationship to examine.

Pre-season baseline concussion testing is considered an important aspect of concussion assessment and accurate testing is needed to improve clinical decision making following injury [7]. Baseline assessment should include a combination of subjective and objective measures, including clinical overview, self-report symptoms, neurocognitive evaluation, and balance testing [8]. Given that vestibular impairments are common following concussion [9], the vestibular/ocular motor screening (VOMS) has received growing consideration as a valid and reliable tool to assess vestibular and ocular motor impairments through patient-reported symptom provocation following concussion [8], which have been recommended for inclusion in post-concussion evaluation [10].

A major consideration of baseline and post-injury research is the effects of pre-existing factors that may modify baseline concussion assessment, such as sex [11], attention/learning problems [12,13], migraine history [14], and mental health [15]. Sleep is one such pre-existing variable that could influence baseline scores on concussion testing. McAllister-Deitrick *et al.* [16] found that in a large sample of college athletes, those with diagnosed sleep disorders (i.e., sleep apnea and insomnia) had higher concussive symptoms during baseline testing. Moran and Ingargiola [17] also showed that athletes who slept <8 h per night before baseline concussion testing showed greater baseline concussion symptoms. It can be surmised that sleep difficulties at baseline testing may influence how these scores can be interpreted for post-concussive assessment. The authors further mentioned a low effect size which calls into question the clinical significance of how sleep disorders may impact baseline concussion testing [17]. Riegler *et al.* [18] reported that college athletes with insufficient sleep may present with symptoms at baseline concussion testing that is similar to post-concussive symptoms in athletes with adequate sleep. Specific to the VOMS, Moran *et al.* found that athletes with a preexisting migraine diagnosis reported worse provocation change scores (i.e., change from pre-test to post-task symptoms) on the VOMS smooth pursuit, convergence, vestibular ocular reflex, and vestibular motion sensitivity tasks [14]. Furthermore, athletes with higher pre-injury anxiety, depression, and anxiety with depression revealed higher scores on baseline concussion symptom report scores [15], while those diagnosed with ADHD had worse scores on the VOMS scales of saccades, convergence, vestibular ocular reflex, and visual motion sensitivity [12].

Regarding sleep assessment, a common mode of measurement is with wearable technology (i.e., wrist actigraphy and fitness trackers). However, given the cost of these tools, they may not always be suitable for mass sleep assessment in athletics. Therefore, self-report sleep questionnaires are often utilized to gain insight into sleep quality. However, general sleep screening questionnaires have limited applicability to the athletic population [19]. The Athlete Sleep Screening Questionnaire (ASSQ) [20] was developed as one such measure to detect clinically significant sleep disturbances and dysfunction in an athletic population and has been determined to be a valid and reliable measurement with acceptable internal consistency [20]. Limited research exists on the use of a self-report sleep difficulty questionnaire with baseline VOMS performance. Therefore, the purpose of the present study was to examine whether sleep disturbance, as measured by the self-report ASSQ, significantly modify symptom provocation on baseline VOMS testing in collegiate athletes.

2. Materials and Methods

2.1. Participants and procedures

A total of 191 collegiate athletes between the ages of 18 and 26 (M = 19.8 ± 1.5 years) from a single academic institution in the Rocky Mountain region consented to participate in the study. Of the sample, 98 (51.3%) identified as female and 93 (48.7%) as male. Regarding academic class in school, there were 48 (25.1%) freshmen, 52 (27.2%) sophomores, 43 (22.5) juniors, 34 (17.8) seniors, and 14 (7.3%) 5th year/graduate students. Participants completed a pre-season baseline VOMS and ASSQ in a counterbalanced manner as part of pre-season sports medicine screening at the participating university.

2.2. Measures

Sleep disturbance was measured using the ASSQ [19-21]. The ASSQ consists of 16 items, with five items used to determine a sleep disturbance score (SDS). In addition, there are four items used to determine a morning (e.g., early bird) or evening (e.g., night owl) chronotype score that is based on a 15-point scale, which reflects their natural inclination of their body to sleep at certain times. A classification is given to respondents as having an evening chronotype (i.e., awake late at night) if their score was ≤4 [4]. Athletes with an evening chronotype are identified as being higher risk for sleep disturbance. Further assessment is recommended for athletes who are placed in the moderate or severe SDS category, have an evening chronotype, or indicate sleep-disordered breathing. The remaining five items are used to evaluate napping frequency, intake of caffeine, use of electronic devices before bed, and travel-related sleep disturbance.

For categorizing individuals into sleep health groups for VOMS comparisons, some ASSQ item responses (Table 1) were categorized appropriately. ASSQ #1 inquiries about recent hours of sleep at night, with responses of 5 – 6, 6 – 7, 7 – 8, 8 – 9, and 9+ h. For this study, we included an additional variable titled "self-reported sleep quantity," which categorized answers into <7 h

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Table 1. ASSQ items, use, and categorization for the study

ASSQ #	Question	Utilized	Category
1	During the recent past, how many hours of actual sleep did you get at night?	Yes	SDS
2	How many naps per week do you take?	No	-
3	How satisfied/dissatisfied are you with the quality of your sleep?	Yes	SDS
4	During the recent past, how long has it usually taken for you to fall asleep each night?	Yes	SDS
5	How often do you have trouble falling asleep?	Yes	SDS
6	During the recent past, how often have you taken medicine to help you sleep?	Yes	SDS
7	Considering only your own feeling best rhythm, at what time would you get up if you were entirely free to plan your day?	No	Chronotype
8	How alert do you feel during the first half hour after having awakened?	No	Chronotype
9	Do you consider yourself to be a morning type person or an evening type person?	Yes	Chronotype
10	Considering only your own feeling best rhythm, at what time would you go to bed if you were entirely free to plan your evening?	No	Chronotype
11	When you are traveling for sport, do you experience sleep disturbance?	Yes	-
12	When you are traveling for sports, do you experience daytime dysfunction?	Yes	-
13	Are you a loud snorer?	No	-
14	Have you been told that you choke, gasp, or stop breathing for periods of time during sleep?	No	-
15	On average, how many caffeinated products do you have per day?	No	-
16	Over the recent past, how often do you use an electronic device within 1 h of going to bed?	No	-

ASSQ: Athlete Sleep Screening Questionnaire

and 7 or more hours of sleep. ASSQ #9 queries about whether the individual self-identifies as a morning or evening chronotype, with responses of definitely a morning type, more a morning type, more an evening type, and definitely an evening type. For this study, we included an additional variable titled "chronotype category," with categorized responses as either morning or evening type. ASSQ #11 and 12 are unscored items that are used for sleep health and clinical decision-making that inquires about when an athlete travels for sport if they experience sleep disturbance (#11) and daytime dysfunction (#12). For this study, those responses were considered independent variables, with dichotomous response as "yes" or "no." Finally, a Sleep Difficulty Score (SDS) is calculated on the ASSQ, by calculating the sum of the responses from ASSQ #1, 3, 4, 5, and 6 on an 18-point scale and is used to identify participants' category of sleep disturbance. These categories include none (SDS of 0 – 4), mild disturbance (SDS of 5 – 7), moderate disturbance (SDS of 8 – 10), and severe disturbance (SDS of 11 – 17). Based on category, appropriate sleep recommendations are outlined. Since moderate and severe scoring both recommend assessment by a sleep medicine physician or qualified sleep professional, those categories were combined into one group (moderate + severe sleep problems) for data analyses. All other ASSQ items, such as snoring or sleep apnea inquiry, were not included in the analyses.

The VOMS is a brief, clinical screening tool that assesses vestibular and ocular impairment and symptom provocation following vestibular-ocular motor tasks in concussion assessment [8,12,22-24]. The VOMS is comprised seven tasks: Smooth pursuits, horizontal and vertical saccades, convergence, horizontal and vertical vestibular ocular reflex (VOR), and visual motion sensitivity (VMS). Before administering the VOMS tasks, the individual is asked to rate their symptoms (pre-test) of headache, dizziness, nausea, and fogginess from 0 (none) to 10 (severe). Following each task, the individual rates their symptoms again, producing a symptom provocation score. VOMS provocation scores as calculated as a change from pre-test scores [25]. For example, if an individual reports a 1 on headache at pre-test and a 2 following smooth pursuits, a 1 symptom provocation score is present for smooth pursuits. An objective measure, near point of convergence (NPC) distance is also recorded during the convergence task [8]. The VOMS is a valid tool for detecting concussion, with a high internal overall consistency, with Cronbach alphas between 0.92 and 0.99 [22,26-28].

2.3. Statistical analyses

General descriptive and inferential statistics were used to summarize all demographic information, ASSQ scores, and VOMS symptoms. A series of Shapiro–Wilk tests were conducted to test for normality. Due to non-normative data, a series of Mann–Whitney *U*-tests were conducted to determine differences between dichotomous (yes or no) variables of sleep disturbance reporting (ASSQ #11), daytime dysfunction reporting (ASSQ #12), chronotype category (ASSQ #9; morning vs. evening), and recent self-reported sleep quantity (<7 and ≥ 7 h) and VOMS symptom provocation. A Kruskal–Wallis H test was conducted to compare SDS category (none, mild, and moderate + severe) on VOMS symptom provocation. A series of Mann–Whitney *U*-tests were conducted between groups for *post hoc* comparisons of significant Kruskal–Wallis H test results. Mean scores are provided for VOMS symptom provocation for ease of clinical application and common clinical scoring. Due to non-parametric data, medians and interquartile ranges were calculated for the sample and between groups.

3. Results

3.1. Sleep health demographics

Of the 191 collegiate athletes in the study, 101 (53%) did not report a sleep disturbance when traveling for sport and 90 (47%) did report a sleep disturbance. Regarding daytime dysfunction

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when traveling for sport, 151 (79%) did and 40 (21%) did not report dysfunction. A total of 109 (57%) athletes reporting getting <7 h of sleep, while 82 (43%) reporting sleeping 7 or more hours. For chronotype, 81 (42.4%) identified as morning type individuals, while 110 (57.6%) identified as evening type individuals. Finally, 67 (35.1%) of athletes were categorized as having no sleep difficulty on the SDS, 69 (36.1%) having mild sleep difficulty, and 55 (28.8%) in the moderate + severe sleep difficulty category. When further breaking down the moderate + severe group, 37 (19.4% of sample) were classified at moderate and 18 (9.4%) as severe sleep difficulty.

3.2. VOMS differences on sleep health when traveling

A series of Mann–Whitney *U*-tests revealed significant differences between sleep disturbance group, with those who reported sleep disturbances when traveling for sport having higher pre-test VOMS symptoms (U = 3316.0, P < 0.001) and symptom provocation on convergence (U = 4125.0, P = 0.015), horizontal VOR (U = 3844.5, P = 0.008), and vertical VOR (U = 4062.0, P = 0.039) than those who did not report a sleep disturbance (Table 2). In addition, those who self-reported daytime dysfunction when traveling for sport reported higher symptoms on pre-test (U = 2199.5, P = 0.002) and provocation on convergence (U = 2734.0, P = 0.042) as compared to those who do not (Table 2). NPC distance also differed between groups, with worse distance in those reporting daytime dysfunction (U = 2195.0, P = 0.007).

3.3. VOMS differences on sleep quantity and chronotype

No group differences existed on any VOMS measures between those who slept <7 and 7 or more hours (U = 3997.5 – 4469.0, P = 0.097 – 0.999; Table 3). Regarding chronotype, evening individuals reported higher symptom provocation on the horizontal saccades than morning type (U = 4145.0, P = 0.033; Table 3). No other differences existed between VOMS items (U = 4098.0 – 4406.5, P = 0.062 – 0.853) and NPC distance (U = 1543.5, P = 0.690).

3.4. VOMS differences on SDS category

The findings of the Kruskal–Wallis H test to compare VOMS performance between SDS category (Table 4) revealed group differences on pre-test symptoms (H(2) = 6.258, P = 0.044) and provocation on horizontal VOR (H(2) = 6.827, P = 0.033), vertical VOR (H(2) = 6.922, P = 0.031), and VMS (H(2) = 6.512, P = 0.039). *Post hoc* analyses revealed worse pre-test symptoms in the moderate + severe SDS group as compared to the none group (U = 1452.0, P = 0.015) and worse provocation on horizontal VOR (U = 1557.5, P = 0.046). Compared to the mild SDS group, the moderate + severe group reported worse symptom provocation on the horizontal VOR (U = 1559.0, P = 0.018), vertical VOR (U = 1584.0, P =0.010), and VMS (U = 1613.0, P = 0.017).

4. Discussion

The purpose of the present study was to examine whether self-reported sleep difficulties influenced symptom provocation

Table 2. Comparison of VOMS pre-test and symptom provocation change scores between sleep disturbance and daytime dysfunction reporting

VOMS item	Sleep disturbance	No sleep disturbance	*P*	Daytime dysfunction	No daytime dysfunction	*P*
Pre-test	1.17±3.3	0.44±1.0	0.001*	2.25±4.1	0.72±1.6	0.002*
Smooth pursuits	0.04±0.2	0.05±0.2	0.612	0.05±0.2	0.05±0.2	0.628
Horizontal saccades	0.09±0.3	0.03±0.1	0.135	0.01±0.3	0.05±0.2	0.453
Vertical saccades	0.14±0.4	0.13±0.5	0.477	0.15±0.4	0.13±0.4	0.475
Convergence	0.19±0.5	0.05±0.3	0.015*	0.20±0.5	0.09±0.4	0.042*
Horizontal VOR	0.44±0.8	0.17±0.4	0.008*	0.48±0.9	0.25±0.6	0.075
Vertical VOR	0.34±0.8	0.12±0.3	0.039*	0.38±1.0	0.19±0.5	0.493
VMS	0.41±1.1	0.11±0.3	0.052	0.43±1.2	0.21±0.6	0.608
NPC distance (cm)	5.48±2.7	4.76±2.2	0.062	6.02±2.7	4.86±2.3	0.007*

Sleep disturbance reporting corresponds to ASSQ #11 as “yes” or “no” responses. Daytime dysfunction reporting corresponds to ASSQ #12 as “yes” or “no” responses

Table 3. Comparison of VOMS pre-test and symptom provocation change scores between self-reported sleep quantity and chronotype

VOMS item	<7 h	≥7 h	*P*	Morning chronotype	Evening chronotype	*P*
Pre-test	1.27±2.8	0.73±1.8	0.139	0.80±1.4	1.21±3.0	0.400
Smooth pursuits	0.05±0.2	0.05±0.2	0.999	0.01±0.1	0.07±0.3	0.124
Horizontal saccades	0.06±0.2	0.05±0.2	0.837	0.01±0.1	0.09±0.3	0.033*
Vertical saccades	0.16±0.5	0.11±0.4	0.688	0.05±0.2	0.20±0.6	0.062
Convergence	0.16±0.5	0.06±0.2	0.250	0.04±0.2	0.17±0.5	0.091
Horizontal VOR	0.35±0.7	0.23±0.5	0.374	0.26±0.5	0.33±0.7	0.853
Vertical VOR	0.27±0.7	0.17±0.5	0.391	0.20±0.4	0.25±0.7	0.725
VMS	0.34±0.9	0.13±0.5	0.097	0.17±0.6	0.31±0.9	0.252
NPC distance (cm)	4.97±2.4	5.28±2.5	0.297	4.99±2.3	5.19±2.6	0.690

Self-reported sleep quantity corresponds to ASSQ #1 as<7 and≥7 h. Chronotype corresponds to ASSQ #9 as self-reported morning or evening type

Table 4. Comparison of VOMS pre-test and symptom provocation change scores between SDS category

VOMS item	None	Mild	Moderate+severe	*P*
Pre-test	0.46±1.0	1.03±2.1	1.75±3.7	0.044[a]
Smooth pursuits	0.04±0.2	0.04±0.2	0.05±0.3	0.923
Horizontal saccades	0.04±0.2	0.06±0.2	0.07±0.3	0.937
Vertical saccades	0.06±0.2	0.17±0.5	0.18±0.5	0.455
Convergence	0.04±0.2	0.12±0.4	0.20±0.6	0.374
Horizontal VOR	0.22±0.5	0.17±0.4	0.55±0.9	0.033[a,b]
Vertical VOR	0.16±0.4	0.12±0.4	0.44±1.0	0.031[b]
VMS	0.12±0.3	0.13±0.5	0.56±1.3	0.039[b]
NPC distance (cm)	5.03±2.6	4.99±2.3	5.34±2.5	0.728

[a]Differences between none and moderate+severe. [b]Differences between mild and moderate+severe

on pre-season VOMS testing in collegiate athletes. Our results indicate that a large portion of the current sample (N = 124; 64.9%) experienced some level of sleep difficulty. Athletes who reported greater sleep disturbance while traveling for sport had worse pre-test concussive symptoms and provocation of symptoms for convergence, horizontal VOR, and vertical VOR. In addition, daytime dysfunction was significantly related to worse pre-test concussive symptoms, symptom provocation on convergence, and NPC distance. While baseline concussion testing is unlikely to occur when traveling for sport, these results still have important implications. If baseline testing is occurring before the beginning of the academic and athletic year (i.e., before start of fall semester), many athletes may be returning to the university from out-of-state locations. It would be wise for the athletic training staff to delay baseline concussion testing until athletes have reacclimated to being back on campus. There may be acute sleep disturbances that occur from traveling back to school, which could negatively influence baseline VOMS testing. Mihalik *et al.* [6] found that in their sample college athletes, one night of poor sleep led to a greater number of reported baseline concussive symptoms, as well as greater severity in symptom scores. Caccese *et al.* [29] also found that in a sample of 30,587 participants, composed of both military cadets and college athletes, poor sleep was a salient factor in leading to higher symptom reporting in those who did not experience a recent concussion. Given this effect, sports medicine professionals need to consider both acute and chronic sleep disturbances in their athletes. Before baseline concussion testing, one strategy may be to have athletes self-report sleep in the week before testing to establish a baseline of normal sleep habits. Once a baseline is established, they can continue to self-report and follow-up with the sports medicine for any patterns of sleep disturbance. Baseline concussion testing may need to be halted until sleep patterns have normalized. As the research has demonstrated, even a single night of poor sleep can significantly alter baseline concussion testing outcomes. This strategy may also aid in identifying athletes who have pre-existing sleep conditions and can be provided further consultation and support with a sleep health professional. In addition, this knowledge will aid the sports medicine staff in having a better interpretation of baseline concussion scores.

As it relates to chronotype, athletes who reported being an evening type had higher symptom provocation on horizontal saccades when compared to athletes who reported being morning types. Zils *et al.* [30] found that one night of sleep deprivation impaired peak velocity saccadic eye movement. However, peak velocity returned to normal after a night of normal sleep. This would indicate that performing baseline VOMS testing after a night of poor sleep may indicate symptoms that would otherwise not be present after a normal night of sleep. McClure *et al.* [31] examined baseline Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) scores among 3686 athletes after a single night of sleep. The authors stratified the athletes into three groups: <7 h of sleep, 7 – 9 of sleep, and >9 h of sleep. Results revealed athletes who slept <7 h reported worse performance on ImPACT baseline testing, while also reporting more baseline symptoms. It should be noted that our present sample showed no significant differences on any baseline VOMS pre-test symptoms or symptom provocation between athletes who slept <7 h and those who slept more. Poor sleep the night before baseline concussion testing can negatively impact symptoms. However, this finding may not be consistent among all athletes. This highlights the importance of an individualized approach when conducting baseline concussion testing. Athletes who regularly get 7 h of sleep per night may experience less dysfunction when receiving <7 h of sleep compared to athletes who routinely get closer to 9 or more hours of sleep.

Results did reveal a significant relationship with SDS on pre-test symptoms and symptom provocation for horizontal VOR, vertical VOR, and VMS. When athletes who reported moderate or severe sleep disturbances were combined into a single category (i.e., moderate + severe SDS), analyses indicated that they reported worse pre-test concussion symptoms compared to athletes who reported no sleep disturbances. Moreover, athletes in the moderate + severe SDS group had worse symptom provocation on the horizontal VOR when compared to athletes who reported no SDS. Athletes in the moderate + severe SDS group further showed worse scores on horizontal VOR, vertical VOR, and VMS when compared to athletes reporting mild SDS. These results further align with the previous research showing that sleep has an important role in the interpretation of baseline concussion testing.

4.1. Limitations and future research

The present study was not without limitations. Sleep was measured as a 1 time assessment and may not accurately reflect objective sleep measurements and chronic sleep quality among participants in the current study. In addition, participants were not screened or queried for the presence of sleep disorders, which may have influenced results. For example, it was not determined before data collection if athletes were suffering from or diagnosed with sleep apnea, restless leg syndrome, or narcolepsy. Concussion history was based on self-report which could introduce accuracy bias as to proper recall of concussive events. Participants were asked to recall the number of diagnosed concussions, which may not accurately reflect the number of actual diagnosed or unreported/undocumented concussions by a medical professional. Future research should examine sleep difficulties and diagnoses between seasons, during travel periods, at night after competition, and after rest/off-days. Further, attempts should be made to determine how SDS score and chronotype may affect other baseline measures of injury assessment not only for concussion, including balance, cognition, and reaction time. In addition, as the ASSQ provides indications of further assessments by a sleep expert for those in moderate or severe SDS category, future research should examine how VOMS provocation may change following interventions.

5. Conclusions

These data reveal that sleep disturbances can cause deleterious effects on baseline symptom reporting and VOMS symptom provocation scores in the absence of a concussive injury. It is warranted that members of the sports medicine staff consider acute and chronic sleep disturbances in their athletes before engaging in pre-season VOMS testing for concussion screenings.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethics Approval and Consent to Participate

Colorado Christian University Institutional Review Board reviewed and approved this study.

References

[1] Brauer AA, Athey AB, Ross MJ, Grandner MA. Sleep and Health Among Collegiate Student Athletes. Chest 2019;156:1234-45.

[2] Duffield TC, Lim MM, Novak M, Lin A, Luther M, Williams CN, *et al*. The Relationship Between Depressive Symptoms, Somatic Complaints, and Concussion History with Poor Sleep in Collegiate Athletes. Sleep Health 2021;7:43-8.

[3] Walsh NP, Halson SL, Sargent C, Roach GD, Nedelec M, Gupta L, *et al*. Sleep and the Athlete: Narrative Review and 2021 Expert Consensus Recommendations. Br J Sports Med 2020;55:356-68.

[4] Bender AM, Van Dongen HP, Samuels CH. Sleep Quality and Chronotype Differences between Elite Athletes and non-athlete Controls. Clocks Sleep 2019;1:3-12.

[5] Lim ST, Kim DY, Kwon HT, Lee E. Sleep Quality and Athletic Performance According to Chronotype. BMC Sports Sci Med Rehabil 2021;13:2.

[6] Mihalik JP, Lengas E, Register-Mihalik JK, Oyama S, Begalle RL, Guskiewicz KM. The Effects of Sleep Quality and Sleep Quantity on Concussion Baseline Assessment. Clin J Sport Med 2013;23:343-8.

[7] Broglio SP, Cantu RC, Gioia GA, Guskiewicz KM, Kutcher J, Palm M, *et al*. National Athletic Trainers' Association Position Statement: Management of Sport Concussion. J Athl Train 2014;49:245-65.

[8] Mucha A, Collins MW, Elbin RJ, Furman JM, Troutman-Enseki C, DeWolf RM, *et al*. A Brief Vestibular/Ocular Motor Screening (voms) Assessment to Evaluate Concussions: Preliminary Findings. Am J Sports Med 2014;42:2479-86.

[9] Hoffer ME, Gottshall KR, Moore R, Balough BJ, Wester D. Characterizing and Treating Dizziness After Mild Head Trauma. Otol Neurotol 2004;25:135-8.

[10] Murray NG, Ambati VN, Contreras MM, Salvatore AP, Reed-Jones RJ. Assessment of Oculomotor Control and Balance Post-Concussion: A Preliminary Study for a Novel Approach to Concussion Management. Brain Inj 2014;28:496-503.

[11] Covassin T, Swanik CB, Sachs M, Kendrick Z, Schatz P, Zillmer E, *et al*. Sex Differences in Baseline Neuropsychological Function and Concussion Symptoms of Collegiate Athletes. Br J Sports Med 2006;40:923-7; discussion 927.

[12] Moran RN, Wallace J, Murray NG, Covassin T. Effects of Attention Deficit Hyperactivity Disorder and Learning Disability on Vestibular and Ocular Baseline Concussion Assessment in Pediatric Athletes. Appl Neuropsychol Child 2021;10:276-82.

[13] Elbin RJ, Kontos AP, Kegel N, Johnson E, Burkhart S, Schatz P. Individual and Combined Effects of LD and adhd on Computerized Neurocognitive Concussion test Performance: Evidence for Separate Norms. Arch Clin Neuropsychol 2013;28:476-84.

[14] Moran RN, Covassin T, Wallace J. Premorbid Migraine History as a Risk Factor for Vestibular and Oculomotor Baseline Concussion Assessment in Pediatric Athletes. J Neurosurg Pediatr 2019;Online ahead of print.

[15] Weber ML, Dean JL, Hoffman NL, Broglio SP, McCrea M, McAllister TW, *et al*. Influences of Mental Illness, Current Psychological State, and Concussion History on Baseline Concussion Assessment Performance. Am J Sports Med 2018;46:1742-51.

[16] McAllister-Deitrick J, Trbovich AM, Broglio SP, McCrea M, McAllister TW, Kontos AP. Effect of Diagnosed Sleep Disorders on Baseline Concussion Symptom, Cognitive, and Balance Assessments in Collegiate Athletes. Am J Sports Med 2020;48:991-9.

[17] Moran RN, Ingargiola A. Self-reported Prior Night's Sleep Quantity on Baseline Symptom Factors and Computerized

DOI: http://dx.doi.org/10.18053/jctres.08.202206.018

Neurocognitive Testing in High School Athletes. Appl Neuropsychol Child 2022;11:62-8.

[18] Riegler KE, Guty ET, Thomas GA, Arnett PA. Sleep Deprived or Concussed? The Acute Impact of Self-reported Insufficient Sleep in College Athletes. J Int Neuropsychol Soc 2021;27:35-46.

[19] Samuels C, James L, Lawson D, Meeuwisse W. The Athlete Sleep Screening Questionnaire: A New Tool for Assessing and Managing Sleep in Elite Athletes. Br J Sports Med 2016;50:418-22.

[20] Bender AM, Lawson D, Werthner P, Samuels CH. The Clinical Validation of the Athlete Sleep Screening Questionnaire: An Instrument to Identify Athletes that need Further Sleep Assessment. Sports Med Open 2018;4:23.

[21] Rabin JM, Mehra R, Chen E, Ahmadi R, Jin Y, Day C. Assessment of Sleep Health in Collegiate Athletes using the Athlete Sleep Screening Questionnaire. J Clin Sleep Med 2020;16:1349-56.

[22] Moran RN, Covassin T, Elbin RJ, Gould D, Nogle S. Reliability and Normative Reference Values for the Vestibular/Ocular Motor Screening (voms) tool in Youth Athletes. Am J Sports Med 2018;46:1475-80.

[23] Moran RN, Cochrane G. Preliminary Study on an Added Vestibular-Ocular Reflex Visual Conflict Task for Postural Control. J Clin Transl Res 2020;5:155-60.

[24] Moran RN, Murray NG, Esco MR, Dobbs W, McAllister-Deitrick J. Effects of Exercise on Symptoms, Vestibular/Ocular Motor Screening and Postural Stability in a College-aged Sample. Concussion 2020;5:CNC73.

[25] Elbin RJ, Eagle SR, Marchetti GF, Anderson M, Schatz P, Womble MN, *et al*. Using Change Scores on the Vestibular Ocular Motor Screening (voms) Tool to Identify Concussion in Adolescents. Appl Neuropsychol Child 2021;11:591-7.

[26] Kontos AP, Sufrinko A, Elbin RJ, Puskar A, Collins MW. Reliability and Associated Risk Factors for Performance on the Vestibular/Ocular Motor Screening (voms) Tool in Healthy Collegiate Athletes. Am J Sports Med 2016;44:1400-6.

[27] Kontos AP, Monti K, Eagle SR, Thomasma E, Holland CL, Thomas D, *et al*. Test-retest Reliability of the Vestibular Ocular Motor Screening (voms) Tool and Modified Balance Error Scoring System (mbess) in us Military Personnel. J Sci Med Sport 2021;24:264-8.

[28] Iverson GL, Cook NE, Howell DR, Collings LJ, Kusch C, Sun J, *et al*. Preseason Vestibular Ocular Motor Screening in Children and Adolescents. Clin J Sport Med 2021;31:e188-92.

[29] Caccese JB, Iverson GL, Hunzinger KJ, Asken BM, Clugston JR, Cameron KL, *et al*. Factors Associated with Symptom Reporting in U.S. Service Academy Cadets and NCAA Student Athletes without Concussion: Findings from the Care Consortium. Sports Med 2021;51:1087-105.

[30] Zils E, Sprenger A, Heide W, Born J, Gais S. Differential Effects of Sleep Deprivation on Saccadic Eye Movements. Sleep 2005;28:1109-15.

[31] McClure DJ, Zuckerman SL, Kutscher SJ, Gregory AJ, Solomon GS. Baseline Neurocognitive Testing in Sports-related Concussions: The Importance of a Prior Night's Sleep. Am J Sports Med 2014;42:472-8.

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