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Sleep health and its association with performance and motivation in tactical athletes enrolled in the Reserve Officers' Training Corps

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ABSTRACT

Objective: To examine habitual sleep health and investigate how habitual sleep duration impacts performance and motivation in Reserve Officers' Training Corps (ROTC) tactical athletes.
Design: Observational.
Setting: A large, state university.
Participants: Fifty-four young tactical athletes enrolled in ROTC.
Measurements: Participants wore wrist actigraph devices and completed sleep diaries for 7 days prior to completing a cognitive/motor test battery.
Results: The mean objective total sleep time of the participants was 6.17 ± 0.69 hours, with only 7.4% of participants averaging ≥7 hours of sleep per day. A mean sleep quality rating between "Poor" and "Fair" was reported by 22.2% of participants. The mean Epworth Sleepiness Scale rating was 8.80 ± 3.24, with 27.8% of participants reporting scores >10. Controlling for age and gender, the average objective total sleep duration was significantly associated with performance on the Symbol Digit Modalities Test ($P = .026$) and with motivation levels to perform the cognitive/motor battery ($P = .016$), but not with performance on the Psychomotor Vigilance Test, Flanker task, Trail Making Test, or Standing Broad Jump.
Conclusions: ROTC tactical athletes habitually sleep less than the recommended 7 hours per day with roughly one-fourth reporting excessive daytime sleepiness and one-fifth reporting poor sleep quality, which may increase their risk for future adverse health outcomes. Longer sleep durations were associated with higher motivation levels and better cognitive processing speed performance; however, they were not associated with executive function, psychomotor vigilance, or broad jump performance.

Introduction

In order to promote optimal health and performance, it has been recommended that adults consistently sleep at least 7 hours per night [1]. Optimal health and performance is especially important in military service members, who are often referred to as "tactical athletes" [2]. Military service members are at an increased risk of insufficient sleep duration [3]. This is of concern considering marksmanship accuracy has been shown to decrease following sleep restriction [4,5] and short sleep durations have been related to the development of mental disorders following combat deployments in a military population [6]. Chronic insufficient sleep has also been associated with sleepiness, mood changes, and cognitive impairments in memory, attention, and alertness [7–9]. In addition to the cognitive consequences of sleep loss, impaired physical performance has been reported, including skill execution, submaximal strength, and muscular power [10]. Considering what can be at stake in military performance, both in the cognitive and physical domains, the consequences of insufficient sleep are of great concern.

The Reserve Officers' Training Corps (ROTC) is the largest commissioning source of officers among all military branches of service [11] and trains tactical athletes to become leaders and decision makers within

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the US military. While it is known that college students, collegiate athletes, and US service members have been found to habitually sleep less than the recommended 7 hours per night [3,12–14], little is known about the sleep health of ROTC tactical athletes. Knowledge about the sleep health in this population will provide awareness and may help develop, test, and implement strategies to optimize the health and readiness of this population. Because these individuals will be in leadership roles in the military, their sleep health has the potential to affect the well-being, health and performance of both themselves and their subordinates.

The objective of this study was to assess sleep health of tactical athletes enrolled in ROTC and to determine whether habitual sleep patterns are associated with cognitive/motor performance and motivation levels. It was hypothesized that ROTC tactical athletes would sleep less than the recommended amounts and that longer sleep durations would be associated with better performance on a cognitive/motor test battery and motivation levels.

Methods

Participants

Students (age 18–30 years) enrolled in a ROTC program at the University of Maryland, College Park were invited to participate in the study. Participants were excluded at the initial screening if they self-reported any of the following: history of psychiatric disorder, take medications with sleep-related side effects, use illicit drugs, average more than 8.5 hours of sleep per 24-hours, extend their sleep by more than 90 minutes per night on weekend nights compared to weekday nights, or if they would not be able to comply with the study procedures after the details were explained to them. The study was approved by the University of Maryland Institutional Review Board and written informed consent was obtained from all participants. A total of 57 participants, who were members of each ROTC branch (Air Force, Army, Navy) provided written consent to participate in the study. Of those, three participants did not complete the study and were excluded from the analyses (two did not wear the wrist actigraph during the study and one actigraph malfunctioned). A total of 54 (20.07 ± 1.75 years, 29 male, 25 female) ROTC tactical athletes completed the study. Table 1 provides demographic information and characteristics of the study population.

Table 1
Demographic Information of Participants

Total study participants	
No. of participants, n	54
Gender	
Male	29 (53.7%)
Female	25 (46.3%)
Age, years	20.07 ± 1.75
Height (m)	1.71 ± 0.09
Weight (kg)	69.19 ± 10.85
BMI (kg/m^2)	23.61 ± 2.59
Trait Anxiety (STAI Y2)	33.44 ± 9.35
State Anxiety (STAI Y1)	31.35 ± 8.85
Ethnicity	
African American	5 (9.3%)
Asian/Pacific Islander	9 (16.7%)
Caucasian/White	39 (72.2%)
Multiracial	1 (1.9%)
ROTC Branch	
Air Force	11 (20.4%)
Army	32 (59.3%)
Navy	11 (20.4%)
College Year	
Freshman	8 (14.8%)
Sophomore	14 (25.9%)
Junior	17 (31.5%)
Senior	12 (22.2%)
Graduate	3 (5.6%)

Data are presented as mean ± standard deviation unless otherwise indicated. BMI = body mass index. STAI = State–Trait Anxiety Inventory.

Sleep–Wake Monitoring

With the goal of measuring sleep–wake patterns in the participants' natural sleep environment, participants wore wrist actigraphs and completed the Consensus Sleep Diary [15] for 7 days prior to performing a cognitive/motor test battery. Actigraphy is known to be a reliable and valid measure to study sleep in natural (e.g., home) environments [16,17] and has been validated against polysomnography [18]. All monitoring started on a Monday to ensure that all participants were on the same weekday/weekend cycle prior to testing. Participants were instructed to wear the Actiwatch 2 (Philips Respironics, Andover, MA) wrist actigraph continuously for the duration of the study with activity data collected in 1-minute epochs. Sleep–wake status for each 1-minute epoch was computed using the Actiware 5.59 scoring algorithm (Actiware software, Philips Respironics, Andover, MA). In conjunction, participants used a sleep diary to record their sleep–wake activity and daily sleep quality (Scored as: 1 = Very Poor, 2 = Poor, 3 = Fair, 4 = Good, 5 = Very Good), and were asked to annotate the diary anytime they removed their wrist actigraph. The consensus sleep diary was used primarily to help validate scoring the actrigraphic data. For example, if there was missing actigraph data (which was minimal), the diary was used to clarify if it was an active period (ie, removing it for a sport competition). Participants received daily reminders via text messaging to keep their actigraph watches on and keep up-to-date on their sleep diaries.

Performance Testing

Every participant conducted testing on a Monday, after the 7 nights of sleep monitoring. Testing was conducted in the same laboratory room with consistent temperature/lighting/noise/etc. To control for the effects of caffeine on performance, participants were instructed to refrain from caffeine ingestion for 6 hours prior to testing.

Testing order and procedures were identical for all participants. Upon arrival for testing, participants confirmed they had not consumed caffeine during the previous 6 hours and completed questionnaires on subjective sleepiness (Epworth Sleepiness Scale (ESS) [19] and Karolinska Sleepiness Scale (KSS) [20]), and anxiety (State–Trait Anxiety Inventory (STAI) [21]). Upon completion of the questionnaires, the participants performed the *Cognitive/Motor Test Battery* with subtests administered in the following order: Psychomotor Vigilance Test (PVT) [22]–5-minute version, Flanker Task [23], the Trail Making Task (A and B) [24], Symbol Digit Modalities Task (SDMT) (written and oral versions) [25], and a maximum standing broad jump (3 times). Following the cognitive/motor test battery, participants were asked to annotate their motivation levels to perform the cognitive tasks (as a whole) and the standing broad jumps using a 100-mm Visual Analogue Scale (VAS) (anchors = No motivation, Highest possible motivation). The average of these two was considered the participant's average motivation level to perform the cognitive/motor battery.

Daytime sleepiness was recorded using the ESS and the KSS. The ESS measures subjective sleep propensity in 8 standardized situations on a 0–3 scale, with higher scores reflecting greater sleepiness. It is a simple and reliable method for measuring sleepiness in adults [26]. The KSS assesses subjective sleepiness on a 9-point scale ranging from 1 (Extremely alert) to 9 (Extremely sleepy, great effort to keep awake, fighting sleep) and has been shown to be a valid measure of extant sleepiness [27]. The STAI was used to measure trait and state anxiety [21] prior to performing the cognitive/motor battery.

A 5-minute modified version of the PVT was administered on the computer using the Psychology Experiment Building Language (PEBL) software program Version 2.0 (licensed under the GNU General Public License) [28]. Each 5-minute trial consisted of stimuli (red circle on computer monitor) occurring at intervals ranging from 2 to 5 seconds after each response from the participant. Participants responded to the stimuli by pressing the spacebar on the keyboard as quickly as possible. The primary outcomes of interest were mean reaction time and number of lapses (reaction times >500 milliseconds).

A modified version of the Flanker Task was administered on the computer using the PEBL software program. Each trial consisted of either congruent (<<<<<, >>>>>) or incongruent (<<> < <, >><>>) arrow stimuli presented on the computer screen, with the middle arrow being the target stimulus. Throughout the task, congruent and incongruent trials appeared in random order and pointed in the right and left direction. The participant pressed the left-shift button with the left index finger if the target stimulus pointed to the left and a right-shift button with the right index finger if the target stimulus pointed to the right. Participants were instructed to respond as quickly and accurately as possible. The inter-trial interval (ITI) was 1000 ms and if the participant responded after 1500 ms, the trial was counted as an error of omission. Participants performed a brief practice trial with three practice stimuli prior to beginning the experimental task. One block of 200 trials was presented, with 100 congruent trials and 100 incongruent trials. Only correct responses were used in the analysis. Mean reaction time on the congruent trials and incongruent trials was calculated. Also, an interference score using the following equation:

$$\frac{incongruent\ mean\ RT - congruent\ mean\ RT}{congruent\ mean\ RT}\ x\ 100$$

was calculated as a metric of inhibitory control unbiased by differences in base reaction time [29–31].

The Trail Making Test A (TMT-A) and B (TMT-B) were administered with pen and paper. Part A (TMT-A) required participants to draw lines between consecutive encircled numbers in ascending order, from 1 to 25. Part B (TMT-B) required participants to draw lines connecting 25 encircled numbers and letters in an alternating progressive sequence (ie, 1 to A to 2 to B) from 1 to 13. Time to completion was measured, and the difference between TMT-B and TMT-A was also calculated [32].

The SDMT was administered with pen and paper. At the top of the page was a key that paired 9 numbers with 9 corresponding geometric figures. Below the key were rows of symbols. Participants were instructed to write, in order, as many numbers associated with symbols as possible within 90 seconds. After the participants completed a written version of the test, they performed an oral version of the same 90-second test, where they verbally instructed the researcher to write in the number with the corresponding symbol. The combination of the written and oral version was calculated as the total score.

The last test administered was a gross motor task: a 'maximum effort' standing broad jump. After receiving instructions and performing three practice jumps, participants stood with their toes behind a start line and were instructed to "jump as far as possible" while landing with both feet. Performance was the measurement from the starting line to the posterior heel that was closest to the start line. Participants performed three jumps and were allowed up to 2 minutes of between-trial recovery between jumps. Performance was measured as the average of the three 'maximum effort' jumps.

Statistical Analysis

All statistical analyses were performed using SPSS 24.0 (IBM Corporation, Armonk, NY, USA). Mean total sleep duration and mean sleep quality were calculated over the 7 days of habitual sleep monitoring. A Pearson correlation was employed to assess the association between objective and subjective sleep data. Mean scores on each questionnaire and test of the cognitive/motor battery were calculated. Multiple linear regression analysis, using age and gender as control variables, was performed to examine the association between objective total sleep duration (independent variable) and performance on each test and subjective questionnaire (dependent variables). Regression coefficient $P < .05$ was considered statistically significant.

Results

Sleep Duration

Mean objective total sleep time (as determined with wrist actigraphy) was 6.17 ± 0.69 hours. Only 7.4% of the participants averaged at least 7 hours of sleep per day, while 53.7% of participants slept between 6.0 and 6.9 hours per day, and 38.9% slept less than 6.0 hours per day. Fig. 1 displays the average sleep duration for each participant. The sleep diary mean total sleep amount was 6.46 ± 0.83 hours, which significantly correlated with the actigraph data (Pearson's $r = .553$, $P < .001$).

Subjective Sleep Quality

Mean subjective sleep quality as measured on the Consensus Sleep Diary was 3.40 ± 0.57, which was between the "Fair" (3) to "Good" (4) range; 18.5% of participants had a mean sleep quality rating equal to or greater than "Good"(4), 59.3% of participants had a mean rating between "Fair"(3) and "Good"(4), and 22. 2% of participants had a mean rating between "Poor"(2) and "Fair" (3).

Subjective Daytime Sleepiness

The mean ESS rating was 8.80 ± 3.24. 18.5% of participants reported scores from 0 to 5 (indicating lower normal daytime sleepiness levels), 53.7% of participants reported scores from 6 to 10 (indicating higher normal daytime sleepiness levels), and 27.8% of participants reported scores >10 (indicating excessive levels of sleepiness). The mean KSS rating was 4.70 ± 1.56, with 38.9% reporting some signs of sleepiness (KSS ≥6). KSS ratings were significantly correlated with ESS ratings (Pearson's $r = .335$, $P = .013$).

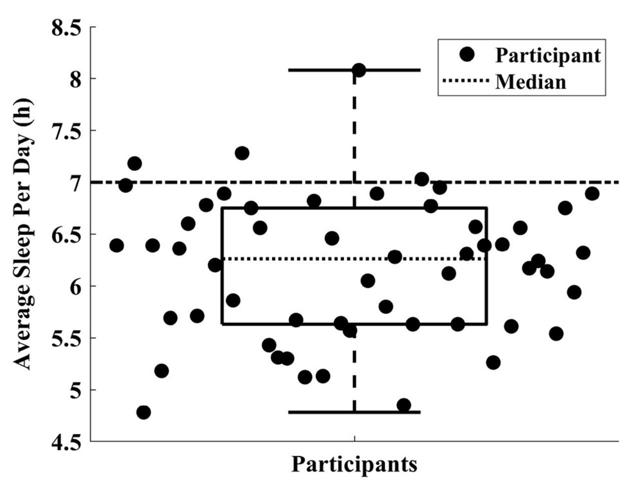

Fig. 1. Boxplot showing each participant's average sleep duration (h) per day measured by actigraphy over 7 days. The horizontal dashed-dotted line represents the recommended 7 hours of sleep, of which, only 4 (7.41%) of the participants averaged more than.

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Cognitive/Motor Battery and Motivation

From the multiple linear regression analysis, after controlling for age and gender, objective total sleep duration was only significantly associated with SDMT performance ($P = .026$) and motivation to perform the cognitive/motor battery ($P = .016$). On average, for each additional hour of sleep duration, SDMT total performance was 8.34 (SE = 3.63) items greater and motivation to perform the cognitive/motor battery was 5.06 (SE = 2.04) mm greater on the VAS. Figs. 2 and 3 show the association between total sleep time and SDMT performance and motivation levels, respectively. No significant associations between habitual total sleep time and any other measures (PVT, Flanker Task, TMT A and B, or Standing Broad Jump (SBJ)) were found. Table 2 outlines the estimated regression coefficients, after controlling for age and gender, for the associations between objective total sleep duration (independent variable) and performance on each test and subjective questionnaire (dependent variables).

Discussion

This is the first study to investigate the sleep health in ROTC tactical athletes and to document the relationship between habitual sleep duration and daytime performance and motivation in this population. Consistent with active duty military populations [12], ROTC tactical athletes obtain insufficient sleep. The mean actigraphic sleep duration in this study was just over 6 hours, below the recommended amount for young adults [1]. ROTC tactical athletes not only obtain less sleep than the recommended amounts, they also appear to sleep less than other undergraduate students[13], including other student-athletes [14]. Over 92% averaged objective sleep durations less than 7 hours per day, a prevalence substantially higher than the 39% reported in a large student-athlete population [14]. The high prevalence of insufficient sleep is concerning considering it has been associated with cognitive and motor impairments [10], marksmanship accuracy decrements [4,5], and increased risk of injuries [33]. Injuries are the biggest health problem of the military services [34], as such, improving sleep health in this population may be a potential mechanism for reducing injuries. Aside from physical injuries, short sleep durations are also related to the development of mental disorders, such as depression, post-traumatic stress disorder, and suicidality, following combat deployments in a military personnel [6]. Poor sleep quality, which nearly one-fifth of the sample reported, has also been associated with negative moods and physical illness in college students [13]. Collectively, ROTC tactical athletes may be at a higher risk for adverse physical and mental health outcomes, which ultimately may negatively impact their ability to perform and lead. ROTC tactical athletes are likely at an increased risk for poor sleep health due to demanding academic and military training schedules. One potential way to improve the sleep health of this population would be to implement education or awareness initiatives into their training that highlight the importance and consequences of healthy sleep habits, as well as different strategies to improve sleep health. Brief educational courses may be a cost-effective way to alleviate sleep problems in young adults[35]. Sleep hygiene education, for example, has shown to improve sleep duration in elite female athletes[36].

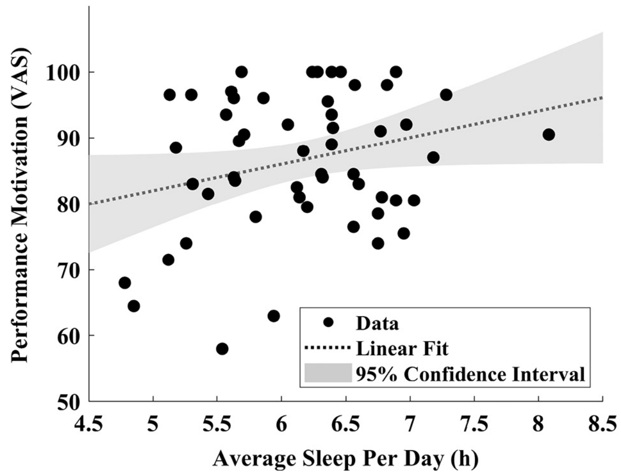

Fig. 3. Association of average sleep time (h) and motivation to perform the test battery. This figure shows the relationship prior to controlling for age and gender and shows that on average, motivation to perform was 4.03 (SE = 2.05) millimeters/percent higher for each additional hour of sleep ($P = .054$). After controlling for age and gender, on average, motivation was 5.06 (SE = 2.04) millimeters/percent higher for each additional hour of sleep ($P = .016$).

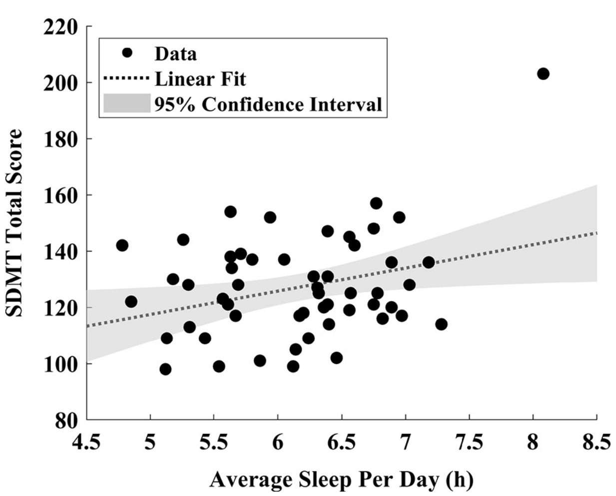

Fig. 2. Association of average sleep time (h) and Symbol Digit Modalities Test (Oral and Written) performance. This figure shows the relationship prior to controlling for age and gender and shows that, on average, SDMT performance was 8.27 (SE = 3.53) higher for each additional hour of sleep ($P = .023$). After controlling for age and gender, on average, SDMT performance was 8.34 (SE = 3.63) higher for each additional hour of sleep ($P = .026$).

Table 2
Multiple Linear Regression Analysis of Each Test and Motivation on Objective Average Total Sleep Duration

	Regression coefficients		
	B	*SE*	Sig. value
PVT			
Lapses	−0.77	0.94	.418
Mean RT (ms)	−9.46	9.78	.338
Flanker Task			
Congruent RT (ms)	0.23	15.37	.978
Incongruent RT (ms)	−7.66	16.43	.643
Interference Score	−1.55	1.16	.188
TMT			
TMT A (s)	−2.44	1.50	.111
TMT B (s)	−3.63	2.78	.117
TMT B-A (s)	−1.18	2.07	.569
SDMT			
Total (Written and Oral)	8.34	3.63	.026*
Standing Broad Jump			
Average (cm)	1.50	4.48	.738
Motivation to perform:			
Cognitive/Motor Battery (mm)	5.06	2.04	.016*

Notes: Changes are per 1 hour of additional sleep; Age and Gender were control variables; Listed in order of performance; * $P < .05$; B = unstandardized coefficient; SE = standard error; PVT = Psychomotor Vigilance Task; TMT = Trail Making Test; SDMT = Symbol Digit Modalities Test; RT = reaction time.

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The findings in this study provide evidence that longer habitual sleep durations are associated with higher motivation levels and better performance on a task commonly used to access cognitive processing speed. Improved task motivation levels may improve performance by increasing "attentional effort" during a task [37], however, only SDMT performance, which has been used as an indicator of information processing speed and efficiency [38,39], was positively associated with longer sleep durations. It was hypothesized that executive function tasks and attention tasks would be impacted by habitual sleep durations because performance on these tasks have been correlated with the prefrontal cortex (PFC) [40,41], one of the regions of the brain, along with the thalamus, and inferior parietal/superior temporal cortex where the greatest reductions in brain activity occur as a result of sleep loss [42]. Habitual sleep duration was not significantly associated with performance on the Flanker task or TMT B-A, both of which are widely used measures of executive functions [32,43], and it did not predict performance on the PVT, which is considered the "gold standard" behavioral measure for sleepiness due to its high reliability, sensitivity to circadian rhythm influences, and absence of learning effects [9,44,45]. While participation of the frontal lobes during executive function tasks is likely necessary, it is also likely that other non-frontal brain regions are necessary [46]. Similarly, aside from the prefrontal region of the brain, psychomotor vigilance (attention) performance has also been associated with activation in the parietal and motor regions, as well as the basal ganglia [41]. It has been previously hypothesized that the extent to which a cognitive process can draw upon associated regions for compensatory support, contributes to the extent to which sleep may impact that cognitive process [45], which may explain the lack of association between habitual sleep amounts and performance on the PVT and executive function measures. In addition, the 5-minute version of the PVT was used in this study and, while it is a viable alternative to the 10-minute version, it may less sensitive to detect small changes in sleepiness [47]. It has also been shown that some individuals have trait-like characteristics that make them resilient to sleep loss, making them less susceptible to performance decrements following a period of sleep restriction [48]. Because of the nature of selection of ROTC tactical athletes, it is possible that these individuals may be more resilient to the effects of sleep loss, which may also explain why no other associations between sleep and other performance metrics were observed. Supportive of this idea is the fact that even though a high percentage (92%) obtained insufficient sleep, a relatively lower percentage (28%) reported excessive daytime sleepiness, which appears less than the 51% found in other college athletes [14]. Lastly, because of the high prevalence of insufficient sleep, there may have not been enough variability in total sleep duration to adequately observe its impact on performance.

This study had limitations. First, this study was a part of a larger study that examined the effects of a sleep manipulation, which excluded participants if they self-reported habitually sleeping more than 8.5 hours a night. While no participant was excluded during the screening process for this reason, there is a possibility that sleep duration estimates may have been biased towards lower values because of the eligibility criteria and thus, the prevalence of insufficient sleepers in this population may be lower. Second, the habitual sleep amount for this study was only measured over 1 week for each participant. Although data collection occurred over the course of the academic semester for all participants, because of fluctuating academic and military training requirements, it is difficult to be certain that this week was representative of their "typical" sleep health. Lastly, because motivation levels were obtained after the participant performed the task, it is possible that their own perception of how they performed the tasks may have confounded how they reported their motivation levels. However, because motivation was associated with sleep duration and most tests were not, this may be unlikely. Future research should consider measuring motivation levels prior to performance.

The main strength of the study was measuring the habitual sleep health, both objectively and subjectively, in 54 ROTC tactical athletes, including 25 females, from each branch of service and utilizing a diverse cognitive/motor battery. In addition, the study controlled for caffeine intake prior to performance testing and controlled for weekend/weekday sleep schedules by starting all participants on the same day of the week.

Future research should focus on how sleep impacts military-relevant performance (ie, physical fitness related testing, marksmanship, etc) and other health-related outcomes (ie, injury rates) in this population. Considering many service members with sleep disturbances frequently manage their symptoms without medical supervision and using various techniques [49], it is important to further investigate ways or techniques to optimize their sleep health. In addition, future studies may include neuroimaging during the performance testing to further understand how differences in habitual sleep duration may be associated with differences in neural dynamics during performance (ie, investigate the cognitive cost/workload during performance to determine if habitual sleep duration is associated with neural efficiency). This may also help better understand how some individuals are more resilient to lower levels of sleep durations.

Conclusions

In this initial study of ROTC tactical athletes training to become leaders in the U.S. military, most of the sample habitually slept less than the recommended 7 hours per day with roughly one-fourth reporting excessive daytime sleepiness and one-fifth reporting poor sleep quality. Longer sleep durations were associated with higher motivation levels and better cognitive processing speed performance; however, they were not associated with executive function, psychomotor vigilance, or broad jump performance. Future research should investigate the extent to which strategies that improve the sleep health of military tactical athletes lead to improved subsequent performance, motivation, and other health-related outcomes.

Disclosure

Material has been reviewed by the WRAIR, there was no objection to its presentation and/or publication. The opinions or assertions contained herein are the private views of the author, and are not to be construed as official, or as reflecting the views of the Department of the Army or the Department of Defense. The investigators have adhered to the policies for protection of human subjects as prescribed in AR 70–25.

Conflicts of Interest

None of the authors have any relevant conflicts of interest to report.

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References

1. Watson NF, Badr MS, Belenky G, et al. Joint consensus statement of the American Academy of sleep medicine and Sleep Research Society on the recommended amount of sleep for a healthy adult: methodology and discussion. *Sleep*. 2015;38(8):1161–1183.
2. Scofield DE, Kardouni JR. The tactical athlete: a product of 21st century strength and conditioning. *Strength Cond J*. 2015;37(4):2–7.
3. Luxton DD, Greenburg D, Ryan J, Niven A, Wheeler G, Mysliwiec V. Prevalence and impact of short sleep duration in redeployed OIF soldiers. *Sleep*. 2011;34(9):1189–1195.
4. McLellan TM, Kamimori GH, Bell DG, Smith IF, Johnson D, Belenky G. Caffeine maintains vigilance and marksmanship in simulated urban operations with sleep deprivation. *Aviat Space Environ Med*. 2005;76(1):39–45.
5. Tharion WJ, Shukitt-Hale B, Lieberman HR. Caffeine effects on marksmanship during high-stress military training with 72 hour sleep deprivation. *Aviat Space Environ Med*. 2003;74(4):309–314.
6. Gehrman P, Seelig AD, Jacobson IG, et al. Predeployment sleep duration and insomnia symptoms as risk factors for new-onset mental health disorders following military deployment. *Sleep*. 2013;36(7):1009–1018.
7. Cote KA, Milner CE, Osip SL, Baker ML, Cuthbert BP. Physiological arousal and attention during a week of continuous sleep restriction. *Physiol Behav*. 2008;95(3):353–364.
8. Gumenyuk V, Roth T, Korzyukov O, Jefferson C, Bowyer S, Drake CL. Habitual short sleep impacts frontal switch mechanism in attention to novelty. *Sleep*. 2011;34(12):1659–1670.
9. Dinges DF, Pack F, Williams K, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. *Sleep*. 1997;20(4):267–277.
10. Fullagar HH, Skorski S, Duffield R, Hammes D, Coutts AJ, Meyer T. Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. *Sports Med*. 2015;45(2):161–186.
11. Oliver JM, Stone JD, Holt C, Jenke SC, Jagim AR, Jones MT. The effect of physical readiness training on Reserve Officers' Training Corps freshmen cadets. *Mil Med*. 2017;182(11):e1981–e1986.
12. Mysliwiec V, McGraw L, Pierce R, Smith P, Trapp B, Roth BJ. Sleep disorders and associated medical comorbidities in active duty military personnel. *Sleep*. 2013;36(2):167–174.
13. Lund HG, Reider BD, Whiting AB, Prichard JR. Sleep patterns and predictors of disturbed sleep in a large population of college students. *J Adolesc Health*. 2010;46(2):124–132.
14. Mah CD, Kezirian EJ, Marcello BM, Dement WC. Poor sleep quality and insufficient sleep of a collegiate student-athlete population. *Sleep Health*. 2018;4(3):251–257.
15. Carney CE, Buysse DJ, Ancoli-Israel S, et al. The consensus sleep diary: standardizing prospective sleep self-monitoring. *Sleep*. 2012;35(2):287–302.
16. Kushida CA, Chang A, Gadkary C, Guilleminault C, Carrillo O, Dement WC. Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters in sleep-disordered patients. *Sleep Med*. 2001;2(5):389–396.
17. Morgenthaler T, Alessi C, Friedman L, et al. Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders: an update for 2007. *Sleep*. 2007;30(4):519–529.
18. Ancoli-Israel S, Martin JL, Blackwell T, et al. The SBSM guide to actigraphy monitoring: clinical and research applications. *Behav Sleep Med*. 2015;13(suppl 1):S4–S38.
19. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep*. 1991;14(6):540–545.
20. Akerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. *Int J Neurosci*. 1990;52(1–2):29–37.
21. Spielberger CD, Gorsuch RL, Lushene R, Vagg PR, Jacobs GA. Manual for the State-Trait Anxiety Inventory. Palo Alto, CA: Consulting Psychologists Press; 1983.
22. Thorne DR, Genser SG, Sing HC, Hegge FW. The Walter reed performance assessment battery. *Neurobehav Toxicol Teratol*. 1985;7(4):415–418.
23. Eriksen BA, Eriksen CW. Effects of noise letters upon the identification of a target letter in a nonsearch task. *Percept Psychophys*. 1974;16(1):143–149.
24. Lezak MD. Neuropsychological Assessment. 3rd ed. New York: Oxford University Press; 1995.
25. Smith A. Symbol Digit Modalities Test: Manual. Los Angeles, CA: Western Psychological Services; 1982.
26. Johns MW. Reliability and factor analysis of the Epworth sleepiness scale. *Sleep*. 1992;15(4):376–381.
27. Kaida K, Takahashi M, Akerstedt T, et al. Validation of the Karolinska sleepiness scale against performance and EEG variables. *Clin Neurophysiol*. 2006;117(7):1574–1581.
28. Mueller ST, Piper BJ. The psychology experiment building language (PEBL) and PEBL test battery. *J Neurosci Methods*. 2014;222:250–259.
29. Wilckens KA, Erickson KI, Wheeler ME. Physical activity and cognition: a mediating role of efficient sleep. *Behav Sleep Med*. 2016:1–18.
30. Colcombe SJ, Kramer AF, Erickson KI, et al. Cardiovascular fitness, cortical plasticity, and aging. *Proc Natl Acad Sci U S A*. 2004;101(9):3316–3321.
31. Liu-Ambrose T, Nagamatsu LS, Voss MW, Khan KM, Handy TC. Resistance training and functional plasticity of the aging brain: a 12-month randomized controlled trial. *Neurobiol Aging*. 2012;33(8):1690–1698.
32. Sanchez-Cubillo I, Perianez JA, Adrover-Roig D, et al. Construct validity of the trail making test: role of task-switching, working memory, inhibition/interference control, and visuomotor abilities. *J Int Neuropsychol Soc*. 2009;15(3):438–450.
33. Milewski MD, Skaggs DL, Bishop GA, et al. Chronic lack of sleep is associated with increased sports injuries in adolescent athletes. *J Pediatr Orthop*. 2014;34(2):129–133.
34. Jones BH, Canham-Chervak M, Canada S, Mitchener TA, Moore S. Medical surveillance of injuries in the US military: descriptive epidemiology and recommendations for improvement. *Am J Prev Med*. 2010;38(1):S42–S60.
35. Kloss JD, Nash CO, Walsh CM, Culnan E, Horsey S, Sexton-Radek K. A "Sleep 101" program for college students improves sleep hygiene knowledge and reduces maladaptive beliefs about sleep. *Behav Med*. 2016;42(1):48–56.
36. O'Donnell S, Driller MW. Sleep-hygiene education improves sleep indices in elite female athletes. *Int J Exerc Sci*. 2017;10(4):522–530.
37. Sarter M, Gehring WJ, Kozak R. More attention must be paid: the neurobiology of attentional effort. *Brain Res Rev*. 2006;51(2):145–160.
38. Wilckens KA, Woo SG, Kirk AR, Erickson KI, Wheeler ME. Role of sleep continuity and total sleep time in executive function across the adult lifespan. *Psychol Aging*. 2014;29(3):658–665.
39. Benedict RH, DeLuca J, Phillips G, LaRocca N, Hudson LD, Rudick R. Validity of the symbol digit modalities test as a cognition performance outcome measure for multiple sclerosis. *Mult Scler J*. 2017;23(5):721–733.
40. Yuan P, Raz N. Prefrontal cortex and executive functions in healthy adults: a meta-analysis of structural neuroimaging studies. *Neurosci Biobehav Rev*. 2014;42:180–192.
41. Drummond SP, Bischoff-Grethe A, Dinges DF, Ayalon L, Mednick SC, Meloy MJ. The neural basis of the psychomotor vigilance task. *Sleep*. 2005;28(9):1059–1068.
42. Thomas M, Sing H, Belenky G, et al. Neural basis of alertness and cognitive performance impairments during sleepiness. I. Effects of 24 h of sleep deprivation on waking human regional brain activity. *J Sleep Res*. 2000;9(4):335–352.
43. Diamond A. Executive functions. *Annu Rev Psychol*. 2013;64:135–168.
44. Van Dongen HP, Maislin G, Mullington JM, Dinges DF. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*. 2003;26(2):117–126.
45. Killgore WD. Effects of sleep deprivation on cognition. *Prog Brain Res*. 2010;185:105–129.
46. Alvarez JA, Emory E. Executive function and the frontal lobes: a meta-analytic review. *Neuropsychol Rev*. 2006;16(1):17–42.
47. Loh S, Lamond N, Dorrian J, Roach G, Dawson D. The validity of psychomotor vigilance tasks of less than 10-minute duration. *Behav Res Methods Instrum Comput*. 2004;36(2):339–346.
48. Rupp TL, Wesensten NJ, Balkin TJ. Trait-like vulnerability to total and partial sleep loss. *Sleep*. 2012;35(8):1163–1172.
49. Lincoln ML, Moore RS, Ames GM. Sleep disturbances after deployment: National Guard soldiers' experiences and strategies. *Sleep Health*. 2018;4(4):377–383.