Examination of Predictors of Physical Readiness Test Performance among US Naval Academy Midshipmen

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ABSTRACT

Introduction: This study aimed to examine relationships between Physical Readiness Test (PRT) performance and self-reported markers of sleep, stress, prior injury history and exercise training frequency in a cohort of USNA midshipmen as well as changes in sleep (quantity and quality) and stress leading up to testing.

Materials and Methods: Midshipmen completed the Pittsburgh Sleep Quality Index (PSQI), Insomnia Severity Index (ISI), and the Perceived Stress Scale (PSS) at baseline and during the week (week 4) in which the PRT was administered. Injury history and exercise frequency surveys were completed at baseline only. The PRT is comprised of two minutes of push-ups conducted on a 2-second cadence, a timed isometric plank-hold, and a timed 1.5-mile run. A paired t-test or Wilcoxon Signed-Rank test was used to examine differences in sleep and stress from week one to four. Pearson product-moment correlations were used to examine relationships between composite scores for the PSQI, ISI, and PSS. Linear regression models were used to examine the relationships between each independent variable and performance of the individual PRT segments.

Results: One hundred fifty-nine (105 men: 54 women) midshipmen were included in this study. A significant difference was found in the mean PSS scores between week one (13.1±5.2) and week four (14.8±7.6) timepoints (p=0.028). At both baseline and week four, positive correlations were found between the PSQI, ISI and PSS. Linear regression models adjusted for sex and age revealed that frequency of running (r=-0.206, P=0.001) and performing calisthenics (r =-0.140, P=0.032) were inversely related to timed-run performance whereas resistance training frequency was positively related to push-up test performance (r=0.215, P<0.001).

Conclusion: The findings indicate increases in perceived stress but no change in sleep quantity and quality over four weeks. Neither self-reported sleep nor perceived stress were associated with individual PRT segments.

INTRODUCTION

Sleep has been identified as a top research topic related to military personnel's health and physical performance.[1,2] It is generally understood that a restorative adult sleep cycle consists of seven to eight hours, during which a person transitions through rapid eye movement and non-rapid eye movement stages.[3] While there is increased recognition among U.S. Military leadership of the importance of restorative sleep on next day performance and physical and mental health, military schedules and environmental conditions faced by younger military recruits are not usually conducive to achieving optimal sleep quantity or quality.[4,5] The academic, athletic and military requirements placed on young adults enrolled at the service academies are equally demanding. Miller et al.[6] demonstrated that incoming U.S. Military Academy cadets who had been fitted with wrist actigraphy monitors received approximately 5 hours and 40 minutes of sleep per night during basic training and 5 hours and 20 minutes of sleep per night during the academic year. Further, data from the Millenium Cohort Study indicate that US service members with no symptoms of insomnia had the greatest proportion of participants who self-reported "good or excellent health" and who experienced the least number of lost workdays, hospitalizations and outpatient medical visits during the ensuing three years.[7] Also, insufficient sleep has been linked to reduced physical performance in athletes and military personnel.[8,9,10] Limited evidence suggests that sleep extension improves physical performance in college students enrolled in military training programs (i.e., Reserve Officers' Training Corps (ROTC)), yet there are no published studies which have examined whether markers of sleep quality or quantity, predict physical performance in young adults enrolled at U.S. service academies.[11]

The Physical Readiness Test (PRT) is used by the United States Naval Academy (USNA) to evaluate the physical stamina of midshipmen as this is a key component of their military preparedness. Completion of the PRT is mandatory for all midshipmen. The performance score is calculated into a military grade and impacts the service assignment of each midshipmen following graduation. Those who fail the test are required to participate in a physical training remediation program which consists of running, calisthenics and mobility training specifically designed to prepare the midshipmen to pass the next semester PRT. Those who repeatedly fail official PRT assessments are at risk for dismissal from the USNA.

Accordingly, the purpose of this study was twofold. First, we evaluated self-reported sleep and stress at baseline and during the week (week 4) of performing a PRT in a group of USNA midshipmen. Second, we examined the relationships between PRT performance and markers of sleep, stress, and prior injury history and exercise training frequency in this group. We hypothesized that (1) self-reported sleep quantity and quality and perceived stress would worsen and (2) poor sleep and greater perceived stress would be related to lower performance on the PRT.

METHODS

The study was completed with a convenience sample of midshipmen who were non-varsity athletes at the USNA between August 2023 and February 2024. All participants were deemed "fit for duty" and required to participate in intramural or club sports. To be included, participants had to be free of any orthopedic injury or health condition at the start of the fall or spring academic semester that would impact their ability to participate in a physically challenging military environment. All research procedures were approved by the USNA Institutional Review Board and in accordance with the Helsinki Declaration of 1975, as revised in 2000. All participants provided written informed consent before participation.

Within the first week of the start of either the fall (August) or spring (January) academic semesters, participants received electronic questionnaires to assess sleep, perceived stress, history of previous injury and specific exercise modality training frequencies (Descriptions below). The injury history and exercise training frequency surveys were administered once whereas participants received the sleep and stress surveys at week one and the week 4 during which they completed the PRT. The PRT was completed four weeks following the start of each academic semester and included the completion of: (1) the greatest number of push-ups in two minutes, while following a 2-second cadence, (2) a timed, isometric plank-hold, and (3) a timed 1.5-mile run. The PRT was conducted in accordance with Physical Fitness Assessment Procedures.

Questionnaires

Pittsburgh Sleep Quality Index. The PSQI is a 19-item self-report questionnaire indexing seven clinically formulated sleep domains: sleep duration, sleep disturbance, sleep latency, daytime disturbance, habitual sleep efficiency, sleep quality, and use of sleep medications. Scores on each of the 7 PSQI subscales are used to calculate a composite score that ranges from 0 to 21. Scores ≤5 are associated with good sleep quality, and scores >5 are associated with poor sleep quality.[12]

Insomnia Severity Index. The ISI assesses the nature, severity, and impact of insomnia. The index evaluates 7 dimensions using a 5-point Likert scale: sleep onset, sleep maintenance, early morning awakening problems, sleep dissatisfaction, interference of sleep difficulties with daytime functioning, noticeability of sleep problems by others, and distress caused by sleep difficulties. The total score can range from 0 to 28 that can be interpreted as absence of insomnia (0–7); subthreshold insomnia (8–14); moderate insomnia (15–21); and severe insomnia (22–28).[13]

Perceived Stress Scale. The PSS is a 10-item self-report instrument that measures perceived stress to various situations in one's life. The scale uses a 0 – 4 Likert scale, with scores ranging from 0 – 40. Higher scores indicate greater perceived stress.[14]

Prior Injury History. The questionnaire was adapted from prior studies and asked separate questions about injuries occurring within the last six months to upper and lower extremity anatomic locations.[15,16] Response categories were "yes" or "no", and an answer of "yes" to any anatomic location indicated a positive prior musculoskeletal injury (MSKI) history. For any location in which an injury history was identified, participants were asked whether they sought medical evaluation from a health care professional as result of the injury. Answers of "yes" indicated a positive prior MSKI history that required medical attention.

Exercise and Sport Participation History. The survey was adapted from a prior study and asked separate questions to identify on average, the frequency (d/wk) in which participants performed exercise and sport modalities in the last six months.[16] Individual exercise items included distance running, sprints, calisthenics, cross-training type exercises, agility drills, aerobic endurance activities (except running), and resistance training. A separate question asked the frequency in which they played sports for at least 30 minutes duration.

Statistical Analyses

Descriptive statistics were calculated for all questionnaire measures. The Shapiro-Wilk test was used to determine if the data were normally distributed. Independent t-tests were used to compare differences between males and females for the PSQI and PSS at week four as the data displayed a standard distribution. Mann-Whitney U tests were used to examine sex-differences for the PSQI and PSS (week 1), and hours of sleep duration and ISI (weeks 1 and 4). Pearson's $\chi2$ for independence were evaluated to determine sex-differences between the frequency of prior MSKI history and exercise modality training frequency. A paired t-test was used to compare differences between PSS scores at week one and four since the data was normally distributed. The Wilcoxon Signed-Rank test was used to compare week one to week four scores for the PSQI, hours of sleep duration, and ISI. Pearson product-moment correlations were used to examine relationships between composite scores for the PSQI, ISI and PSS at both weeks one and four. Associations were interpreted as very weak (0 – 0.19), weak (0.20 – 0.39), moderate (0.40 – 0.59), strong (0.60 – 0.79), and very strong (0.80 – 1.0). Univariate and multivariate linear regression models were used to examine the relationships between each independent variable and run time for a 1.5-mile run, number of push-ups completed in 2 min, and a timed plank-hold test. Independent variables included week four total scores for the PSQI, ISI, and PSS, hours of sleep duration (week 4), exercise modality training frequency (d/wk), and presence of prior MSKI. Each dependent variable was analyzed as a continuous variable. For each multivariate model, sex and age were included as covariates. An alpha level of ≤ 0.05 was used to determine statistical significance. Data analyses were performed using Statistical Package for the Social Sciences version 20.0 (SPSS, Inc., Chicago, IL, USA).

RESULTS

One hundred fifty-nine midshipmen (age= 20.6 ± 1.4 years; men: 105; women: 54) were included in this study. Sixty-eight completed the study in fall 2023 while the remaining 91 participated in spring 2024. Sex differences for all questionnaire variables are presented in Table 1. As shown, PSS week one score and both the percentage of participants reporting any prior history of MSKI within the last six months and injuries requiring medical evaluation were greater for female than male participants. For participants who completed the PSS at both timepoints, the week one PSS score was 13.1 ± 5.2. The week four PSS score was 14.8 ± 7.6. A statistically significant difference was found in the mean PSS score between week one and week four timepoints ($p = 0.028$). No significant differences were found for the PSQI, ISI and hours of sleep duration between week one and four.

Tables 2a and 2b display the Pearson's correlation coefficients between total scores for the PSQI, ISI, and PSS. For both weeks one and four, the PSQI was positively correlated with the ISI and PSS, and the ISI was positively related to the PSS.

Table 3 shows the relationships between all questionnaire variables and each PRT measure. Frequency of running ($r = – 0.206$, $P = 0.001$) and performing calisthenics ($r = – 0.140$, $P = 0.032$) were both inversely related to timed-run performance, after controlling for sex and age. Univariate analysis revealed an inverse relationship between resistance training frequency and run-time ($r = – 0.208$, $P = 0.032$). Likewise, participants reporting a prior MSKI history that required medical evaluation had slower run-times ($r = 0.297$, $P < 0.001$). Resistance training frequency was positively related to push-up test performance ($r = 0.215$, $P < 0.001$) after controlling for sex and age. Previous history of MSKI requiring medical evaluation was negatively related to the number of completed push-ups ($r = – 0.203$, $P = 0.026$) in the univariate analysis only.

DISCUSSION

The present study yielded the following observations. USNA midshipmen with better sleep quality had lower perceived stress. Yet, while perceived stress increased, self-reported sleep parameters remained unchanged over the course of the study. As expected, our results indicate an inverse relationship between frequency of running and performing calisthenics and timed 1.5-mile run performance. Similarly, a positive relationship was found between resistance training frequency and the number of push-ups completed in two minutes. However, contrary to our stated hypothesis, neither self-reported sleep nor perceived stress were related to performance on the individual PRT segments. Considering the limited previous work on this topic, the present findings add to the literature in the several meaningful ways.

We found that midshipmen who reported better quality sleep (i.e., a lower PSQI composite and ISI total score) were more likely to report lower perceived stress. These data corroborate longitudinal findings in military personnel[7] and suggest that interventions aimed at enhancing sleep quantity and quality of midshipmen may, in turn, improve their capacity to cope with, or overcome exposure to adversity or stress.[17] The potential long-term implications of these data are illustrated by Wang et al.[18] who report that US Army soldiers suffering from pre-deployment insomnia and stress are at an increased risk for post-traumatic stress disorder (PTSD) and suicidal ideation upon return from deployment. Still, we have demonstrated that mean sleep duration (~ 6h) in a large sample of men and women enrolled at the USNA falls short of what is recommended for adults to optimize general health (7-8h).[3] These data are consistent with what has been previously observed in USMA cadets,[6] albeit the use of different sleep assessment methodologies (e.g., self-reported vs. actigraphy) between studies preclude direct comparisons. Also, our evaluation of

Table 1: Descriptive statistics for questionnaire data of participants presented as means ± standard deviations and 95% confidence intervals.

Variable	Participants (n)	Females	Males
PSQI (week 1)	F=49; M=98	6.4 ± 2.6 (5.6, 7.1)	6.1 ± 2.5 (5.6, 6.6)
PSQI sleep duration (hours) (week 1)	F=49; M=98	6.18 ± 1.09 (5.87, 6.48)	6.24 ± 1.03 (6.04, 6.45)
PSQI (week 4)	F=28; M=70	6.3 ± 2.6 (5.3, 7.3)	5.8 ± 2.6 (5.2, 6.4)
PSQI sleep duration (hours) (week 4)	F=28; M=70	6.02 ± 1.10 (5.66, 6.38)	6.20 ± 0.90 (5.97, 6.43)
ISI (week 1)	F=48; M=99	6.4 ± 4.1 (5.2, 7.5)	7.0 ± 4.7 (6.1, 7.9)
ISI (week 4)	F=30; M=64	8.2 ± 5.6 (6.5, 10.0)	6.4 ± 4.6 (5.2, 7.6)
PSS (week 1)*	F=51; M=100	15.6 ± 6.7 (13.7, 17.5)	13.1 ± 5.8 (12.0, 14.3)
PSS (week 4)	F=27; M=58	15.8 ± 6.8 (12.9, 18.7)	14.0 ± 7.8 (12.0, 15.9)
Run frequency (d/wk)	F=41; M=82	2.6 ± 1.2 (2.2, 3.0)	2.6 ± 1.3 (2.3, 2.9)
Sprint frequency (d/wk)	F=41; M=82	1.5 ± 1.0 (1.2, 1.8)	1.2 ± 1.0 (1.0, 1.4)
Calisthenics frequency (d/wk)	F=41; M=82	2.2 ± 1.6 (1.7, 2.7)	2.7 ± 1.8 (2.3, 3.1)
Cross-training frequency (d/wk)	F=41; M=82	1.5 ± 1.2 (1.1, 1.9)	1.4 ± 1.4 (1.1, 1.7)
Agility frequency (d/wk)	F=41; M=82	0.5 ± 1.0 (0.1, 0.8)	0.4 ± 1.0 (0.2, 0.6)
Aerobic endurance frequency (d/wk)	F=41; M=82	1.5 ± 1.7 (0.9, 2.0)	1.7 ± 1.7 (1.3, 2.1)
Resistance training frequency (d/wk)	F=41; M=82	1.9 ± 1.4 (1.5, 2.3)	2.7 ± 1.7 (2.3, 3.0)
Sport frequency (d/wk)	F=41; M=82	1.7 ± 2.1 (1.0, 2.3)	1.8 ± 1.7 (1.4, 2.2)
% with previous MSKI*	F=45; M=95	60.0	41.1
% with previous MSKI† (medical attention)	F=45; M=95	46.7	22.1

PSQI: Pittsburgh Sleep Quality Index; ISI: Insomnia Severity Index; PSS: Perceived Stress Scale; MSKI: musculoskeletal injury; d/wk= days per week **P* < 0.05, †*P* < 0.01

Table 2a. Pearson correlation coefficients between behavioral questionnaire components at week 1.

Variable	PSQI	ISI	PSS
PSQI	--		
ISI	0.575**	--	
PSS	0.365**	0.383**	--

PSQI: Pittsburgh Sleep Quality Index; ISI: Insomnia Severity Index; PSS: Perceived Stress Scale **P < 0.001.

Table 2b. Pearson correlation coefficients between behavioral questionnaire components at week 4.

Variable	PSQI	ISI	PSS
PSQI	--		
ISI	0.602**	--	
PSS	0.290*	0.530**	--

PSQI: Pittsburgh Sleep Quality Index; ISI: Insomnia Severity Index; PSS: Perceived Stress Scale **P* < 0.01; ***P* < 0.001

self-reported sleep quality in USNA revealed that the mean global PSQI score was 6.2, which is indicative of "poor" quality sleep.[12] Underlying sleep disorders (e.g., insomnia and sleep apnea) that commonly cause sleep disruption are predictive of poor mental and cardiovascular health outcomes.[19,20] Indeed, a strong association was observed between the PSQI composite score and the ISI total score. Fortunately, although we did not evaluate sleep apnea directly, the mean ISI score of 6.9 suggests an "absence of insomnia" in our cohort.[13] Further, we posited that the high stakes nature of the PRT might confer an emotional/mental burden that would manifest as increased perceived stress and, in turn, significantly alter sleep behavior, but our data did not bear this out entirely. While perceived stress increased from week 1 to week 4, self-reported sleep quality and duration did not change, suggesting that even if increased perceived stress were associated with the impending physical challenge, it did not rise to a level that compromised sleep.

In this cohort, timed run and push up test performance were correlated with the frequency of running and resistance training, respectively, implying that underlying fitness is a major predictor of physical performance. Although training frequency was self-reported and no direct measurements of aerobic capacity or muscular endurance were performed at the time of baseline survey completion, these findings are not surprising since prior studies have highlighted the impact of these select physical fitness attributes on both military performance tasks and injury risk. Specifically, greater aerobic capacity has been found to be related to better performance in a timed obstacle course and a warrior task simulation while muscular endurance assessed by the number of push-ups completed in 60s was predictive of performance in a novel military simulation test.[21,22,23] Worth noting is that a prior review indicated that lower levels of exercise training frequency and physical activity prior to enlistment were related to higher rates of attrition in military basic training recruits.[24] Thus, our findings support the need for midshipmen to prioritize running and resistance training frequency as part of their overall academic and military training responsibilities.

Table 3: Relationships between questionnaire data and PRT performance.

	Relationship with Run-time		Adjusted Relationship with Run-time		Relationship with Push-ups		Adjusted Relationship with Push-ups		Relationship with Plank-hold		Adjusted Relationship with Plank-hold	
	r	P	r	P	r	P	r	P	r	P	r	P
PSQI (week 4)	-0.017	0.875	-0.095	0.250	-0.004	0.970	0.088	0.248	0.046	0.664	0.025	0.831
PSQI sleep duration (week 4)	-0.025	0.816	0.047	0.550	-0.027	0.801	-0.109	0.131	-0.009	0.933	0.004	0.971
ISI (week 4)	0.083	0.447	-0.066	0.413	-0.210	0.053	-0.038	0.589	-0.161	0.135	-0.202	0.073
PSS (week 4)	0.088	0.447	-0.034	0.691	-0.139	0.232	0.012	0.869	-0.018	0.875	-0.027	0.823
Run frequency	-0.170	0.081	-0.206	**0.001**	-0.067	0.495	-0.032	0.612	-0.039	0.690	-0.042	0.673
Sprint frequency	0.112	0.253	0.006	0.931	-0.104	0.289	0.023	0.714	-0.125	0.203	-0.143	0.157
Calisthenics frequency	-0.233	**0.016**	-0.140	**0.032**	0.122	0.214	0.025	0.694	-0.038	0.701	-0.030	0.764
Cross-training frequency	-0.080	0.411	-0.127	0.052	0.024	0.805	0.053	0.403	0.067	0.497	0.077	0.445
Agility frequency	0.022	0.822	-0.016	0.805	0.024	0.809	0.069	0.269	-0.059	0.550	-0.059	0.553
Aerobic endurance frequency	-0.154	0.113	-0.113	0.085	0.077	0.434	0.029	0.642	0.056	0.568	0.062	0.535
Resistance training frequency	-0.208	**0.032**	-0.065	0.342	0.322	**<0.001**	0.215	**<0.001**	0.124	0.207	0.124	0.232
Sport frequency	-0.073	0.456	-0.077	0.242	0.071	0.469	0.079	0.212	0.063	0.521	0.070	0.484
Any previous MSKI	0.172	0.058	0.044	0.499	-0.117	0.205	0.031	0.598	0.051	0.576	0.047	0.621
MSKI (medical attention)	0.297	**<0.001**	0.096	0.150	-0.203	**0.026**	0.039	0.524	0.022	0.809	0.013	0.895

PSQI: Pittsburgh Sleep Quality Index; ISI: Insomnia Severity Index; PSS: Perceived Stress Scale; MSKI: musculoskeletal injury.

Contrary to our hypothesis, measures of sleep were not related to any individual PRT segment in this cohort. Lagoy and colleagues found in military personnel that lower habitual daytime sleepiness (a marker of inadequate sleep assessed by the Epworth Sleepiness Scale (ESS)) was predictive of next day performance on the tactical mobility test, which consists of seven tasks that assess operationally relevant aspects of physical performance.[9,25] Also, Ritland et al. reported that extending nightly sleep across four nights resulted in improved broad jump performance among tactical athletes enrolled in the Reserve Officers' Training Corps.[11] Together, these previous observations suggest that compromised sleep quality and quantity can hinder gross motor tasks as well as cognitive performance.[9,11] However, we emphasize that according to Lagoy et al., neither PSQI nor ISI predicted performance on the tactical mobility test.[9] Thus, the metric through which sleep is characterized may account for disparate findings between or within studies. To this point, others found a weak relationship between PSQI and ESS in a community sample of middle-aged and older adults, implying that these self-report scales capture independent physiological dimensions of sleep-wake symptoms, which may, in turn, differentially impact physical performance.[26] Further, upon viewing our results in the context of the Ritland et al. report, we speculate that there may be a sleep duration "threshold" that must be achieved in order for improvements in physical performance to occur.[11] Notably, Ritland et al. observed improvements in broad jump performance after increasing sleep duration of ROTC tactical athletes from 6.2 to 7.6 hours (a 23% change in sleep duration).[11] By comparison, the midshipmen in the present study self-reported sleeping ~ 6.1 hours but no relation with sleep duration performance on the timed run, push-up test and plank hold were observed. Our data corroborate those of Edgar et al. who reported no advantage in improved 2.4-km run time or maximum press ups and curl-ups performed following a six-week physical training course among New Zealand Defense Force Officer trainees who slept on average, 6.27 hours per night over 36 nights compared to counterparts who slept 5.51 hours per night over 36 nights.[10] Clearly, further studies are required to determine the optimal duration of sleep for maximizing physical performance in military cohorts.

Limitations

We remain cautious in our interpretation of this data considering several limitations. First, 91 of the 159 midshipmen who completed self-report questionnaires repeated the questionnaires at week four. Our initial attempt to collect self-report data on a weekly basis was met with logistical challenges and lost data that ultimately reduces statistical power. Similarly, we relied on sleep questionnaires to evaluate sleep quality and quantity, whereas wrist-worn actigraphs, used previously by others provide an objective assessment of sleep quantity and aspects of sleep quality that include sleep latency, sleep efficiency and wake after sleep onset.[9,11,27] Thus, our ability to draw definitive conclusions may be limited. Also, we did not collect prospective markers of physical or mental health, and any attempts to link poor sleep with negative future health consequences is purely speculative. Finally, we note that all but one participant passed the PRT and the range of scores was narrow, which limits our capacity to identify performance predictors. A larger cohort of midshipmen that includes individuals who failed the PRT is needed for more robust, decisive analysis. Typically, between 100-125 midshipmen (~2.7%) from across the academy fail each semester. The lack of heterogeneity in the sample, regarding PRT performance, provides the justification for assessing sleep, and perceived stress in all midshipmen prior to performing the PRT.

In conclusion, markers of poor sleep quality were related to greater perceived stress across the study, suggesting that practicing good sleep hygiene habits may have a positive impact on how midshipmen cope with stress. Further, while our findings reinforce the importance of physical conditioning on PFT performance in USNA midshipmen, whether enhancing sleep quality or quantity leads to performance benefits warrants further investigation.

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