The Effect of Habitual Exercise on Daytime Sleepiness and Mood of US Navy Sailors

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As part of a broader study, this work investigates if habitual exercise protects against mood deterioration and daytime sleepiness in Sailors during underway operations. Previous work has shown that unfavorable watchstanding schedules have negative effects on sleep quality, subjective levels of fatigue, mood, and psychomotor vigilance performance. The participants were crewmembers of a U.S. Navy aircraft carrier (N=193), working on two different watchstanding schedules. Epworth Sleepiness Scale (ESS) and profile of mood state (POMS) scores were compared between participants who reported exercising < 3 times/week and ≥3 times/week. During the course of the underway, ESS and POMS scores changed more favorably for the crewmembers who exercised 3 or more times/week compared to their peers who exercised less. The effect of working out was more prominent in the less favorable shift schedule. These results suggest that habitual exercise can be a protective buffer against some of the negative effects of watchstanding while underway.

INTRODUCTION

Background

The living and working conditions of ship crews are notorious for inducing fatigue and sleep deprivation (Miller, Matsangas, & Kenney, 2012). Shiftwork, minimally manned crews, long workdays, austere berthing spaces and limited privacy are all factors that contribute to the negative effects of life at sea (Arendt, Middleton, Williams, Francis, & Luke, 2006; Sallinen & Kecklund, 2010; Åkerstedt & Wright, 2009).

Multiple studies conducted at the Naval Postgraduate School have shown that United States Navy sailors' sleep, fatigue, mood and performance is affected by the working and living conditions onboard (Miller et al., 2012; Miller, Matsangas, & Shattuck, 2008). Some of the daily work/rest schedules (or watchbills) employed result in circadian misalignment, i.e., workdays that differ in length from the naturally-occurring, 24-hour circadian day (Colquhoun, Blake, & Edwards, 1968). For example, using a 5-hrs on/10-hrs off ("5 & Dime" or "5/10") leads to a 15- or 30-hour day in length, without the opportunity to sleep about the same time each day. The work schedules continuously cycle without weekends or time off for recovery.

The typical workday at sea, however, involves much more than watchstanding and as a result, crewmembers work long hours and suffer from sleep deprivation, sleep fragmentation, suboptimal performance, and worrisome levels of alertness (Miller et al., 2012; Paul, Ebisuzaki, McHarg, Hursh, & Miller, 2012; Shattuck & Matsangas, 2015b).

While underway, some Sailors choose to work out during their off-duty time. It is well known that exercise has positive acute and long-term effects on mood, fatigue and general health and well-being (Byrne & Byrne, 1993; Driver & Taylor, 2000; Yeung, 1996). Moreover, habitual physical activity can moderate the negative effect sleep deprivation has on mood after periods of constant wakefulness. That is, habitually more active participants show less mood deterioration after sleep deprivation (Meney, Waterhouse, Atkinson, Reilly, & Davenne, 1998). It is unclear, however, if exercise habits are associated with daytime sleepiness and mood of sailors perfoming their duties while underway.

Study goals

The goal of this study was to investigate the association between exercise, mood and fatigue. It was hypothesized that having an exercise routine would protect against mood deterioration and daytime sleepiness during underway operations.

This work is part of a multi-year project to assess and compare the fatigue levels, workload, and performance of crewmembers working on various watchstanding schedules (Shattuck & Matsangas, 2014, 2015a; Shattuck, Matsangas, & Waggoner, 2014). The data we used herein had been collected to assess the differences between the 3-hrs on/9-hrs off (3/9) and the 5-hrs on/10-hrs off (5/10) watchstanding schedules. Detailed results are presented elsewhere (Brown, Matsangas, & Shattuck, 2015; Shattuck & Matsangas, 2015b; Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015).

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METHOD

Participants

Participants (N=193, 24.8±3.60 years of age, 156 males) were volunteers from the nuclear reactor (RX) department of the aircraft carrier USS NIMITZ (CVN-68). All participants were performing their normal daily duties standing watch on the 3-h on/9-h off (3/9) schedule (n=119), or on the 5-h on/10-h off (5/10) schedule (n=74).

Procedures

This study was a naturalistic observation with data collected during two time periods. In the first data collection, data were collected during a 17-day underway period while the participants were working on the 5/10 watchstanding schedule. Approximately 5 months after the first, the second data collection was conducted during an 11-day underway period while the participants were working on the 3/9 schedule.

The 5/10 is a 3-section watchstanding schedule in which a crewmember stands watch for five hours followed by a 10-hour off watch period (Shattuck, Matsangas, & Powley, 2015). The continual rotation of the 5/10 iterates every three days and results in work and rest occurring at different times each day. Such rotating work/rest patterns have long been associated with sleep problems and circadian dysyncrony (Colquhoun & Folkard, 1985; Goh, Tong, Lim, Low, & Lee, 2000; Hakola & Härmä, 2001). Divided into one of four watch sections, crewmembers on the 3/9 stood watch for three hours followed by 9-h off watch. The daily watch schedule of the 3/9 is fixed where crewmembers stand watch at the same time each day.

The participants filled out the pre-study questionnaires and received sleep watches and activity logs at the start of the data collection. Upon completion of the study, participants completed an end-of-study questionnaire. The survey tools included demographic information (age, gender), as well as three standardized mood and fatigue-related questionnaires. Participants were asked whether they had an exercise routine while underway and reported the type, duration, and frequency of their exercise routine.

To measure mood states and assess changes in mood, participants filled out the profile of mood state (POMS) questionnaire (McNair, Lorr, & Droppelman, 1971). The POMS is a standardized, 65-item inventory originally developed to assess mood state in psychiatric populations. The questionnaire assesses the dimensions of the mood construct using six subscales: anger–hostility (12 items; range 0–48), confusion– bewilderment (7 items; range 0–28), depression (15 items; range 0–60), fatigue (7 items; range 0–28), tension–anxiety (9 items; range 0–36) and vigor–activity (8 items; range 0–32). Total mood disturbance (TMD) score ranges from -32 to 200 and is derived by subtracting the vigor subscale score and summing the scores of the remaining five subscales. The POMS was administered using the instruction set: 'Describe how you felt during the past two weeks'. The Epworth Sleepiness Scale (ESS) was used to assess average daytime sleepiness (Johns, 1991). Actigraphic devices backed up by information in activity logs were used to assess crewmembers' sleep (Shattuck, Matsangas, & Brown, 2015; Shattuck, Matsangas, & Powley, 2015).

Because it was part of a larger study, the questionnaires included additional information that is not included in this work. The study protocol was approved by the Naval Postgraduate School Institutional Review Board.

Analysis

Statistical analysis was conducted with a statistical software package (JMP Pro 12; SAS Institute; Cary, North Carolina). Data are presented as mean (M) ± standard deviation (SD) or median (MD), as appropriate. Significance level was set at $p < 0.05$. Initially, all variables underwent descriptive statistical analysis to determine demographic characteristics of the study population. To explore the association between exercise frequency and variables of interest (average daytime sleepiness and mood), classification trees were constructed using recursive partitioning analysis (RPA). Next, crewmembers were divided into two groups based on the results of the RPA. The first group included participants who reported exercising less than 3 times per week ("<3"), whereas the rest of the crewmembers were included in the "≥3" group.

The data were assessed and rejected for normality using the Shapiro–Wilk W test; therefore, comparisons were based on nonparametric methods. The changes in ESS and POMS scores between the beginning and end of the study were calculated for each individual (delta values). The association between exercise and mood and sleepiness was assessed by comparing the two exercise groups ("<3", "≥3"). The Mann-Whitney U- test and Fisher's Exact test were used for pairwise comparisons.

RESULTS

Approximately 63% of the participants reported having an exercise routine while underway. They worked out on average four times per week (median value), ranging from two to seven times, with a median duration of 60 minutes (ranging from 30 to 120 minutes). Neither percentage of crewmembers exercising, nor the weekly frequency of exercising differed by watchstanding schedule (for all pairwise comparisons, p>0.15).

Crewmembers who participated in our study were sleep deprived, receiving on average 6.77±0.936 hours of daily sleep compared to the eight hours considered the physiologically acceptable amount of daily sleep. There were no statistically significant differences in hours of sleep between the two exercise groups, or in sleep quality measured by the Pittsburgh Sleep Quality Assessment (all p-values >0.30, data not shown). As shown elsewhere, however, crewmembers working on the 5/10 received worse quality of sleep compared to their peers working on the 3/9 (Shattuck & Matsangas, 2015b; Shattuck, Matsangas, & Brown, 2015). Consequently, daytime sleepiness and mood states deteriorated during the underway when using the 5/10, whereas daytime sleepiness and mood states of Sailors on the 3/9 did not change.

Analysis showed that at the beginning of the study, the two exercise groups did not differ in terms of their ESS or POMS scores (all comparisons, p>0.20). During the course of the underway, however, ESS and POMS scores changed more favorably for the crewmembers who exercised three or more times per week compared to their peers working out less than three times. As assessed by ESS scores, average daytime sleepiness increased by approximately 1.2 points during the underway for the less physically active crewmembers (group "<3" in Table 1). In contrast, the average daytime sleepiness of more active participants remained the same (group "≥3" in Table 2). This pattern of differences was also seen in sailors' mood as assessed by POMS TMD scores, as well. Specifically, the change in mood of the crewmembers working on the 3/9 differed depending on exercise group. Mood of less physically active crewmembers remained the same during the underway. In contrast, the mood of crewmembers exercising three or more times per week improved on average by 5 points. Mood worsened during the underway in the 5/10 participants. This deterioration, however, was significantly less for the crewmembers who exercised three or more times per week. The beneficial effect of exercising is evident in almost all differences in average daytime sleepiness and mood scales shown in Table 1. These results are further evident in Figures 1 and 2.

Specifically, Figure 1 shows the change in ESS scores, and in POMS TMD scores by exercise frequency group and watchstanding schedule. In Figure 2 we elaborate further on the POMS subscales.

DISCUSSION

Previous work has shown that the fixed 3/9 is better than the rotating 5/10 in terms of sleep quality, subjective levels of fatigue, mood, psychomotor vigilance performance, and acceptance by the Sailors (Brown et al., 2015; Shattuck, Matsangas, & Brown, 2015). The results we presented in the paper, however, suggest that habitual exercise can be a protective buffer against some of these negative effects of watchstanding while underway. The protective effect of working out was more prominent in the less favorable shift schedule, the rotating 5/10. It should be noted that the causal relationship between exercise and mood cannot be determined by the current study design. Mood and daytime sleepiness could be affected by a number of factors, such as work tasks, sleep and caffeine consumption. However, the hours of sleep and sleep quality, as well as caffeine consumption, were similar in the two exercise groups.

Table 1. Sleep, average daytime sleepiness, and mood changes by watchstanding schedule and exercise group (M ± SD).

Watch schedule	**3/9**			**5/10**		
Exercise Group	<3 (n=49)	≥3 (n=69)	p-value	<3 (n=32)	≥3 (n=42)	p-value
Δ(ESS)	1.20±3.91	-0.508±3.41	0.069*	1.28±2.94	0.524±4.20	0.194
Δ(POMS TMD)	0.106±27.4	-5.37±23.0	0.363	18.1±23.8	5.55±19.0	0.011*
Δ(Tension-Anxiety)	-1.19±4.05	-1.27±4.57	0.291	1.84±4.52	-0.24±3.91	0.068*
Δ(Depression)	-0.255±9.01	-2.00±6.27	0.650	5.39±9.32	0.263±6.35	0.006*
Δ(Anger-Hostility)	0.426±8.40	-0.507±7.18	0.515	5.36±7.80	3.08±7.62	0.215
Δ(Vigor-Activity)	-2.13±3.88	-0.866±5.24	0.219	-2.19±4.00	-2.13±3.75	0.947
Δ(Fatigue)	0.277±5.03	-1.60±5.21	0.033*	2.55±4.36	0.605±4.02	0.008*
Δ(Confusion-Bewilderment)	-1.28±3.06	-0.866±3.06	0.260	0.774±3.22	-0.290±2.80	0.113

* p<0.1

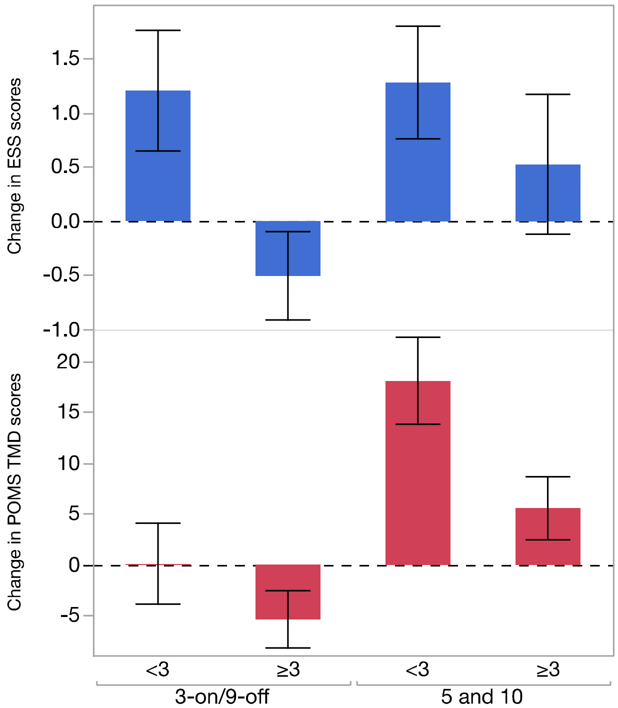

Figure 1. Change of ESS and POMS TMD scores by exercise frequency and watchstanding schedule. Vertical lines denote the Standard Error of the Mean (SEM).

In addition, previous work clearly showing that exercise can improve mood and sleepiness and protect against mood deterioration due to sleep deprivation (Byrne & Byrne, 1993; Driver & Taylor, 2000; Meney et al., 1998; Yeung, 1996) support our suggestion that exercise is the cause of these positive mood changes.

The <3 group did not meet, and the ≥3 group exceeded the minimal weekly physical activity recommendations of the American College of Sports Medicine (Haskell et al., 2007). Our suggestion is therefore that these guidelines can be used for recommendations of physical activity during underway operations.

Some concerns have been raised about physical exercise having negative effects on performance in sleep deprived individuals (Scott, McNaughton, & Polman, 2006). In studies of total sleep deprivation, bouts of exercise have been shown to both increase and decrease cognitive and motor performance. LeDuc et al., (2000) found that bouts of exercise could ameliorate some of the increases in sleepiness and fatigue associated with sleep loss for a short period of time, but exercise did not prevent performance decrements. However, these were laboratory studies and may not apply to sailors performing their duties while underway. Future studies should investigate how habitual exercise affects performance in real-life operational settings.

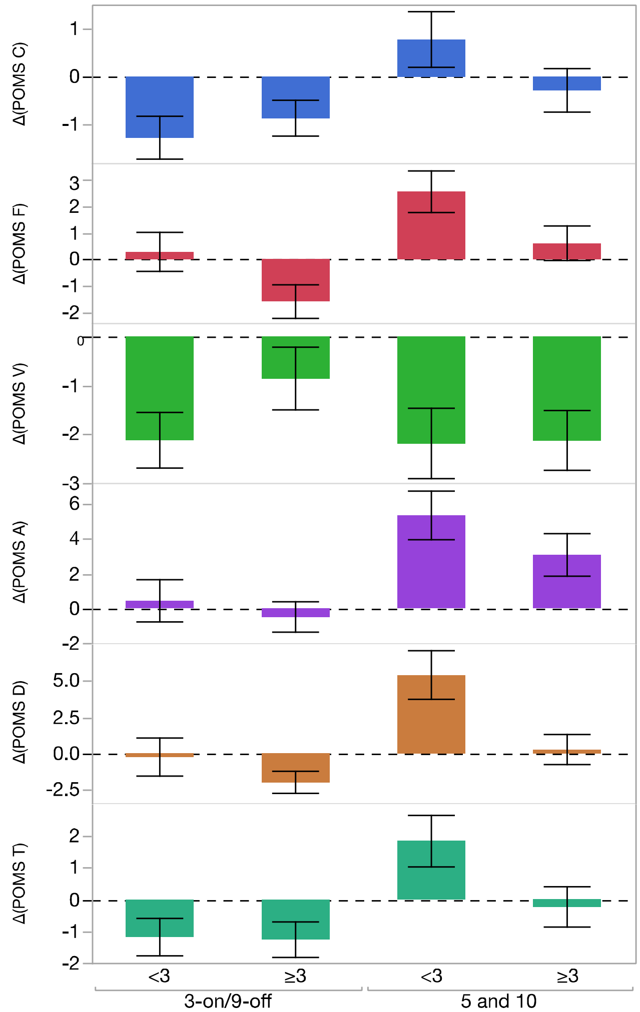

Figure 2. POMS sub-scales scores by exercise frequency. Vertical lines denote the Standard Error of the Mean (SEM).

Study limitations

This operational study has a number of caveats. First, the study was a naturalistic observation rather than an experiment. All participants were volunteers performing their normal daily duties; there was no randomization in the assignment to watchstanding schedule or exercise routine. Individuals who exercise during shipboard activities may be in better physical condition to begin with, or may be more adaptable to shipboard conditions. Participants were asked about their exercise routine at the beginning of the study. Future efforts will assess exercise behavior on a daily basis. The time between pre- and post-study assessments was 11 to 17 days. A longer follow-up could reveal long-term effects of physical activity on mood and fatigue in this population.

Disclaimer

The views expressed in this study are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, or the U.S. Government.

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