Sleep Health 8 (2022) 542–550

Contents lists available at ScienceDirect

Sleep Health

Journal of the National Sleep Foundation

journal homepage: sleephealthjournal.org

Circadian, light, and sleep skills program: Efficacy of a brief educational intervention for improving sleep and psychological health at sea

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ARTICLE INFO

Article History:
Received 25 February 2022
Revised 24 May 2022
Accepted 29 May 2022

Keywords:
Circadian
Sleep
Light
Education
Military
Health promotion
Intervention

ABSTRACT

Objectives: Military service poses unique threats to sleep and circadian health, and the shipboard environment presents further challenges. Disrupted sleep and circadian rhythms are linked to myriad health and safety issues that compromise readiness, including negative psychological health outcomes. Thus, one advantage of mitigating sleep problems includes the possibility of also enhancing mental health.
Procedures: We evaluated the efficacy of the Circadian, Light, and Sleep Skills program for shipboard military personnel for improving sleep, and examined the impact of sleep on mental health in participating sailors. Questionnaires were administered to US sailors (N = 150) assigned to three ships (one control, two intervention) before the program (T1), immediately afterward (T2), and 2-4 months later, after a period at sea (T3). Outcomes included motivation to improve sleep; sleep and circadian knowledge; frequency of sleep-promoting behaviors; sleep quality (Pittsburgh Sleep Quality Index); and mental health symptoms. Satisfaction with specific program elements and perceived relevance were also examined.
Main findings: Sleep and circadian knowledge, frequency of sleep-promoting behaviors, and sleep quality improved from T1 to T3 in the intervention versus control group. Sleep quality also mediated the effects of the underway (at sea) period on mental health. The intervention was well received, with high satisfaction and perceived relevance ratings.
Principal conclusions: A brief 30-min intervention before an underway period improved sleep, circadian, and psychological health outcomes in shipboard sailors, even months later. Broader dissemination of this program may provide significant positive impact with minimal investment of resources.

Introduction

Poor sleep and circadian health represent enduring, ubiquitous issues within the military. Service members often face circadian disruption due to shiftwork schedules, nighttime operations, travel across time zones, and early rise times that may not align with their internal rhythms—all potential contributors to the sleep disturbances that are common among this population.[1-3] Recent studies have reported that over half of active duty service members (ADSM) sleep fewer than the recommended 7-9 h per night,[4-7] and as many as one in 9 sleep for 4 hours or less.[7] Further, over one quarter of ADSM report a lack of energy due to insufficient sleep.[7] When left unaddressed or untreated, poor sleep habits may become disorders that increase in severity over time.[1] This bears out in evidence indicating that as many as one in 6 ADSM report clinically meaningful symptoms of insomnia,[8] and that rates of disorders such as insomnia and obstructive sleep apnea have risen over the past 2 decades.[9]

Disruptions of both sleep and the circadian timing system pose a serious threat to safety and to psychological and physical health, both directly (eg, cardiovascular function, metabolism) and indirectly (eg, caffeine and nicotine usage).[10] For example, research suggests that sleep and circadian disturbance have acute negative effects on cognitive performance and decision-making,[11,12] and that chronic sleep restriction can result in significant cognitive deficits, equivalent to those observed after 24 h of sleep deprivation or with a blood

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https://doi.org/10.1016/j.sleh.2022.05.010
2352-7218/

alcohol content of 0.1%.[13] These deficits can lead to other issues—several studies among ADSM have noted an inverse relationship between sleep duration and frequency of occupational accidents or mistakes that could affect mission performance.[14,15] Additionally, ADSM who report short sleep duration and/or insomnia are more likely to report psychological health issues, including symptoms of depression, anxiety, and posttraumatic stress disorder (PTSD), compared to those without sleep issues.[16,17] While the relationship between sleep and psychological health can be bidirectional, a growing body of evidence suggests that insufficient or disturbed sleep prior to and during military operations may lead to poorer mental health outcomes following deployment and beyond.[17-19] For example, in a large sample of ADSM, self-reported insomnia symptoms prior to deployment were associated with new-onset mental health symptoms upon return.[17]

Sleep deficiencies can have particularly severe outcomes in ADSM, and therefore it is critical to develop and empirically evaluate interventions that can improve sleep and circadian health. Recently, the Department of Defense introduced various forcewide initiatives designed to mitigate known barriers to optimal sleep and circadian rhythms. These include the Navy's adoption of circadian watchbills,[20] which aim to minimize work schedule-induced circadian disruption, and the Army's inclusion of sleep as a key tenet of the "Performance Triad" (https://p3.amedd.army.mil/), which takes a step toward changing cultural norms surrounding sleep. While these efforts begin to address institutional barriers to sleep and circadian health, evidence suggests educational interventions that focus on individual-level factors, such as sleep-related knowledge, attitudes, and behaviors, are also needed. Indeed, a 2015 RAND report determined that programs that increase sleep health awareness, knowledge, and behaviors among ADSM may be particularly useful.[3]

Despite the identified need for military sleep education and the promise some of these types of interventions have shown in civilian populations,[21,22] few such efforts have been formally evaluated in service members. Limited studies, however, have offered positive results. One recent study by Adler and colleagues[23] evaluated a sleep education program in US Army leadership and found improvements in leader and unit member attitudes, knowledge, and sleep health in the intervention versus control group. Similarly, a sleep education program administered to German Armed Forces personnel demonstrated select improvements in multiple indicators of sleep health, though changes in attitudes, knowledge, and sleep-promoting behaviors were not assessed.[24]

These recent studies of sleep education in military populations are encouraging but continued efforts are warranted. For instance, there remains a need for interventions that are tailored, with consideration for the specific challenges of service members in different branches of the military and/or particular operational contexts. It has been well established that the experiences of seafarers present unique challenges to healthy sleep and underlying alignment of circadian rhythms,[25,26] and thus tailored sleep education programs should explicitly address the circadian disruption caused by shiftwork schedules, early starts, intercontinental travel, and other military-specific issues.[1,3] Most existing sleep-related behavioral programs focus on insomnia or "sleep hygiene" and pay little attention to, or ignore altogether, chronobiological concepts such as circadian rhythms and the physiological effects of light.[24,27,28] Further, to our knowledge, no sleep and/or circadian-focused educational programs have been formally evaluated among shipboard sailors. The present study attempted to fill those gaps by evaluating the efficacy of a novel, sleep-focused educational program tailored for sailors, called the Circadian, Light, and Sleep Skills program for Shipboard Military personnel (CLASS-SM). The efficacy of the intervention was evaluated in terms of changes in sleep-related knowledge, motivation, sleep-promoting behaviors, and sleep quality over multiple months. Additionally, given the known associations between sleep and mental health, we also examined whether changes in sleep quality mediated the relationship between intervention participation and psychological health outcomes.

Methods

Participants

Participants were crew members of 3 US Navy ships: one littoral combat ship (LCS) and two Arleigh Burke-class destroyer amphibious ships. The ships were selected based on their operational schedule. Because this intervention was designed to help improve sleep in shipboard settings, sailors aboard ships with upcoming underway periods of at least 2 weeks were invited to participate. Individuals receiving clinical therapies (eg, cognitive behavioral therapy for insomnia [CBT-I], prescription sleep aids) for a diagnosed sleep condition at the time of recruitment were ineligible. This exclusion criterion was applied to minimize confounding and because the sleep program was not designed to replace clinical treatment for diagnosed sleep disorders. All but one study volunteer were eligible to participate.

CLASS-SM program

CLASS-SM is a novel sleep and circadian health education program developed by chronobiologists (EMH & GLG) for shipboard sailors that provides information intended to increase sleep-promoting behaviors in operational contexts. The 30 min, in-person presentation was designed to maximize engagement through the use of interactive components and evidence-based examples derived from military- and shipboard-specific research. The program includes the following content areas: an overview of sleep, circadian rhythms, and the physiological effects of light; the importance of sleep and circadian rhythms to health and occupational performance; and strategies to improve sleep, circadian health, and alertness both at home and in operational settings. The in-person component also deliberately focused on circadian rhythms and was structured such that information and tips were presented across an individual's day, from waking to bedtime, rather than simply focusing on behaviors in general or just those that surround the main period of sleep. In addition to the in-person presentation, participants received up to 4, once-weekly text messages delivered on consecutive weeks, beginning approximately 2 weeks following intervention completion. The messages were designed to briefly reinforce concepts discussed in the presentation. The program was informed by leading sleep therapies (eg, CBT-I) and health behavior change theories (eg, Health Belief Model), and was tailored specifically to the priority population of shipboard sailors (intervention development and feasibility are described elsewhere).[29]

Procedure

This study used a 2-group, quasi-experimental trial design. Sailors were assigned to a study condition a priori based on the ship to which they were assigned; those on the LCS and one of the Arleigh Burke-class destroyer amphibious ships were assigned to the intervention group, and those aboard the second destroyer were assigned to the control group. Group assignment by ship was employed to prevent contamination across participants. The 2 destroyers had the same mission and underway period.

Approximately 2 weeks prior to going underway, participating sailors were invited to attend one in-person study event. At this event, both groups completed a baseline questionnaire (T1). Afterwards, control group participants were excused with no intervention exposure, while the intervention group participated in the CLASS-SM presentation and completed an immediate follow-up questionnaire (T2) from which a subset of data is reported elsewhere.[29] In addition, a longer term follow-up survey was administered electronically to both groups within 1 month of returning from sea, 2-4 months after T2 (T3). Data collection occurred between October 2018 and June 2020. Unless otherwise specified, analyses compared data from T1 and T3. The study protocol was approved by the Institutional Review Board of the Naval Health Research Center, and all participants provided their free and informed consent.

Measures

Personal characteristics and military history

At T1, participants reported age, education, gender, rank, and deployment history. Chronotype, or the degree to which someone identifies as a morning or evening person, was also collected only at T1 via the reduced version of the Morningness–Eveningness Questionnaire (5 items).[30] The scale resulted in a continuous measure of morningness (0-25) that was binned into 5 categories: definitely morning type, moderately morning type, neither type, moderately evening type, and definitely evening type.

Motivation to improve sleep health

At all time points (T1-T3), motivation was assessed with a novel 5-item scale adapted from previous research.[31,32] Items included, “It is very important for me to maximize my sleep health” and “I want to learn new strategies to improve my sleep health”, which were rated on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). A mean scale score was computed for analysis (α = 0.799).

Sleep-related knowledge

At all 3 time points, 7 items developed by our team assessed knowledge related to topics addressed in CLASS-SM, such as, “How many hours of sleep per night are recommended for adults?” and “Approximately how long does it take your circadian system to adjust when you change your light schedule by three hours (by flying from one US coast to the other)?” Knowledge scores were generated as a percent correct.

Sleep-promoting behaviors

At T1 and T3, participants were asked to report whether they engaged in 17 behaviors known to improve sleep quality (0 = No, 1 = Yes;) *for the purpose of improving their sleep* over the previous 2 months while at sea; one item regarding alcohol usage was excluded because consumption is forbidden while underway. Sum scores were computed to indicate the number of behaviors used (range: 0-16; α = 0.736). These data from the first participating ship (the LCS) were not included in analyses because the original survey items did not specify the context in which the behaviors took place (ie, ship vs at home); the survey was updated for subsequent ships to explicitly ask about shipboard-specific behaviors.

Sleep quality

The primary outcome of interest in this study was sleep quality over the preceding month, which was measured at T1 and T3, using the 19-item Pittsburgh Sleep Quality Index (PSQI).[33] One global score and seven component scores (subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction) were derived. Higher scores denoted poorer PSQI outcomes; a score greater than 5 is generally considered indicative of poor sleep quality.

Program satisfaction

At T2, intervention participants reported relevance of the primary content areas (general sleep, circadian rhythms, and sleep-promoting behaviors) using a scale from 1 (*not at all relevant*) to 7 (*extremely relevant*). Additionally, participants reported satisfaction with the presentation overall as well as its length, format, content, and coverage (1 [*extremely dissatisfied*] to 7 [*extremely satisfied*]). Participants were also asked if they learned something new, if they were likely to use that information, and if they were likely to share that information with others.

Psychological health

Symptoms of depression and anxiety were assessed at T1 and T3 via the 8-item Patient Health Questionnaire[34] (α = 0.860) and 7-item generalized anxiety disorder assessment[35] (α = 0.907), respectively (T1 and T3). Each measures the frequency of various symptoms in the prior 2 weeks, from 0 (*not at all*) to 3 (*nearly every day*). PTSD symptoms were assessed with the 20-item PTSD Checklist for DSM-5 (PCL-5; α = 0.953),[36] which quantifies the degree to which respondents were bothered by symptoms over the past month, from 0 (*not at all*) to 4 (*extremely*). Items were summed to create total scale scores for each measure.

Psychological resilience was assessed at T1, using the 6-item Brief Resilience Scale.[37] Participants mark the degree to which they agree with statements regarding their typical response to stress. Response options range from 1 (*strongly disagree*) to 5 (*strongly agree*). The mean of all items were used to create a scale score (α = 0.850).

Analysis

Descriptive statistics (ie, means, frequencies) were computed for all variables to examine distribution. *T*-tests and chi-square analyses were used to examine differences between participating study ships and study groups, and to conduct attrition analyses. Since the primary study aim was to determine the effect of intervention participation on 4 factors that may influence sleep health (ie, sleep-related motivation, knowledge, behaviors [participants from the 2 destroyers only], and sleep quality), a series of four repeated measures analysis of covariance models were computed to examine potential changes in scores between T1 and T3. Means and standard deviations were determined for demographic variables and estimated marginal means, and standard errors were determined for models. Model covariates included age, gender, and chronotype. All statistical tests were evaluated at the 0.05 alpha level.

Exploratory analyses

In addition to the primary analyses, mediation analyses were conducted to determine if changes in sleep quality mediated the relationship between intervention participation and psychological health outcomes, using the SPSS PROCESS macro version 3.5 (IBM SPSS Statistics, Armonk, NY). The PROCESS macro yielded standardized regression estimate (β) scores and multiple correlations squared (R^2), which were interpreted with traditional effect sizes: .01-0.059 = small, 0.06–0.139 = moderate, and $\geq$.14 = large. In line with current recommendations for mediation analyses, the bootstrapping method with 5000 resamples to estimate the 95% CI was conducted to examine the significance of indirect effects. Covariates included age, gender, chronotype, psychological resilience, and baseline sleep quality and psychological health symptoms.

Analyses were conducted in SPSS version 25 or GraphPad Prism (GraphPad Software, San Diego, CA).

Results

Of the 298 sailors who enrolled in the study and completed T1/T2 activities, n = 150 (50.3%) also completed the T3 assessment. Attrition analyses comparing characteristics of participants who completed all time points and those who were lost to follow-up showed that the only significant difference between those who completed the study and those who did not was rank, with more high-ranking sailors completing the study, $\chi^2(4)$ = 16.5, $P < .01$. The following results include only the data for those who completed all applicable time points.

Participant demographics are shown in Table 1. Most participants were male (82.7%), and 62.0% were between the ages of 18 and 29 years. There were no differences between intervention and control groups in terms of gender, marital status, race/ethnicity, or education (all $P > .34$). There were baseline group differences in rank, $\chi^2(3)$ = 13.154, P = .004; chronotype, $\chi^2(4)$ = 9.64, P = .047; and age, t(148) = −2.52, P = .013, with the intervention group being relatively older, higher in rank, and more morning type. There were also no baseline group differences in symptoms of depression, anxiety, or PTSD ($P > .05$). Characteristics of participants from each of the three study ships are shown in Supplemental Table 5.

Table 1
CLASS-SM program participant characteristics

	Total n (%) or M (SD)	Intervention	Control
Gender			
Male	124 (82.7)	55 (82.1)	69 (83.1)
Female	26 (17.3)	12 (17.9)	14 (16.9)
Age, years			
17–24	53 (35.3)	19 (28.4)	34 (41.0)
25–29	40 (26.7)	16 (23.9)	24 (28.9)
30–39	50 (33.3)	26 (38.8)	24 (28.9)
40+	7 (4.7)	6 (9.0)	1 (1.2)
Race/ethnicity[a]			
White	62 (41.3)	27 (40.3)	35 (42.2)
Black	20 (13.3)	7 (10.4)	13 (15.7)
Hispanic	28 (18.7)	13 (19.4)	15 (18.1)
Asian or Pacific Islander	21 (14.0)	10 (14.9)	11 (13.3)
Native American or Alaskan or Multi-racial	19 (12.7)	10 (14.9)	9 (10.8)
Marital status			
Married/cohabitating	67 (44.7)	31 (46.3)	36 (43.4)
Divorced/widowed	15 (10.0)	9 (13.4)	6 (7.2)
Never married	68 (45.3)	27 (40.3)	41 (49.4)
Pay grade/rank			
E1-E3	41 (27.3)	12 (17.9)	29 (34.9)
E4-E6	72 (48.0)	34 (50.7)	38 (45.8)
E7-E9	16 (10.7)	13 (19.4)	3 (3.6)
Officer	21 (14.0)	8 (11.9)	13 (15.7)
Education			
High school	59 (39.3)	26 (38.8)	33 (39.8)
Some college	40 (26.7)	16 (23.9)	24 (28.9)
Two-year degree	17 (11.3)	9 (13.4)	8 (9.6)
Four-year degree or higher	34 (22.7)	16 (23.9)	18 (21.7)
Chronotype			
Definitely morning type	6 (4.0)	4 (6.0)	2 (2.4)
Moderately morning type	52 (34.7)	28 (41.8)	24 (28.9)
Neither type	77 (51.3)	26 (38.8)	51 (61.4)
Moderately evening type	14 (9.3)	9 (13.4)	5 (6.0)
Definitely evening type	1 (0.7)	0 (0.0)	1 (1.2)
Depression Symptoms (M)	6.73 (4.62)	6.25 (4.27)	7.04 (4.84)
Anxiety Symptoms (M)	5.72 (4.70)	5.11 (4.26)	6.13 (4.95)
PTSD Symptoms (M)	15.77 (16.01)	12.89 (14.19)	17.67 (16.93)

CLASS-SM, Circadian, Light, and Sleep Skills program for Shipboard Military personnel; E, enlisted; *M*, mean; SD, standard deviation
[a] Participants selected all that applied for race/ethnicity.

Sleep motivation

Motivation to improve sleep was high: for both groups at baseline (T1; 4.14 ± 0.06 and 4.05 ± 0.07 for control and intervention groups, respectively); immediately after the presentation (T2) in the intervention group (unadjusted mean, 4.00 ± 0.08); and following the underway period (3.89 ± 0.21 and 3.80 ± 0.23). From T1 to T3, there was no significant effect of time, F(1, 144) = 0.08, P = .77; group condition, F(1, 144) = 0.32, P = .57; or their interaction, F(1, 144) = 0.00, P = .98).

Sleep knowledge

Baseline percent correct was comparable between groups (control: 48.3% ± 0.1, intervention: 50.0% ± 2.4), and scores were higher at T3 in the intervention group only (47.7% ± 2.1 for control, 71.9% ± 2.4 for intervention). Group condition, F(1, 145) = 24.14, P = .000, and the Group × Time interaction were significant, F(1, 145) = 36.69, P = .000, η_p^2 = 0.20, whereas time was not, F(1, 145) = 0.01, P = .93 (Fig. 1A). Immediately following the intervention (T2), percent correct within individuals who completed all 3 time points (intervention group only, n = 58) was 88.9% ± 13.7 (unadjusted mean). Though all 7 knowledge items improved over time in the intervention group, correct responses that improved the most from T1 were for a question on the number of hours of sleep per 24 h recommended by experts and a question on the circadian potency of short wavelength ("blue") light.

Sleep-promoting behaviors

When examining T1 and T3 data, there were no main effects of group or time, F(1, 103) = 0.06, P = .81, and F(1, 103) = 0.53, P = .47, respectively), but there was a Group × Time interaction, F(1, 103) = 4.75, P = .032, η_p^2 = 0.05 (Fig. 1B). There was also a main effect of chronotype, F(1, 103) = 6.14, P = .015, with evening types engaging in more sleep-promoting behaviors in general. No other covariates or their interactions were significant (all $P > .17$). On average, intervention participants adopted roughly 2 new behaviors, whereas the control group adopted none. Paired t tests (n = 23-28, see Methods section and Table 2) revealed statistically significant increases in the percentage of individuals in the intervention group employing the following sleep-promoting behaviors while at sea: using relaxation techniques before bed and avoiding light, caffeine, exercise, and alerting activities in the hours just before bedtime (Table 2).

Sleep quality

Global PSQI scores began at comparable levels at baseline (8.69 ± 0.36 for control and 8.54 ± 0.39 for intervention). There was a main effect of condition, F(1,130) = 4.22, P = .042, but not time, F(1, 130) = 1.06, P = .31. In addition, there was a significant Time × Condition interaction, F(1, 130) = 7.84, P = .006, η_p^2 = 0.06, with scores from T1 to T3 increasing in the control group and decreasing in the intervention group (Fig. 1C; lower scores indicate greater sleep quality). *When examining the specific components of the PSQI, those that improved over time for the intervention group* were sleep quality, sleep latency (time to fall asleep), and sleep efficiency (Table 3). Chronotype was significant in the global PSQI model (P = .028), with trends for age and the Chronotype × Time interaction (P = .058 and P = .052, respectively); evening types started out with relatively more sleep disruption but did not worsen across time points, whereas disruption increased in morning types. No other covariates or their interactions reached significance (all $P > .15$).

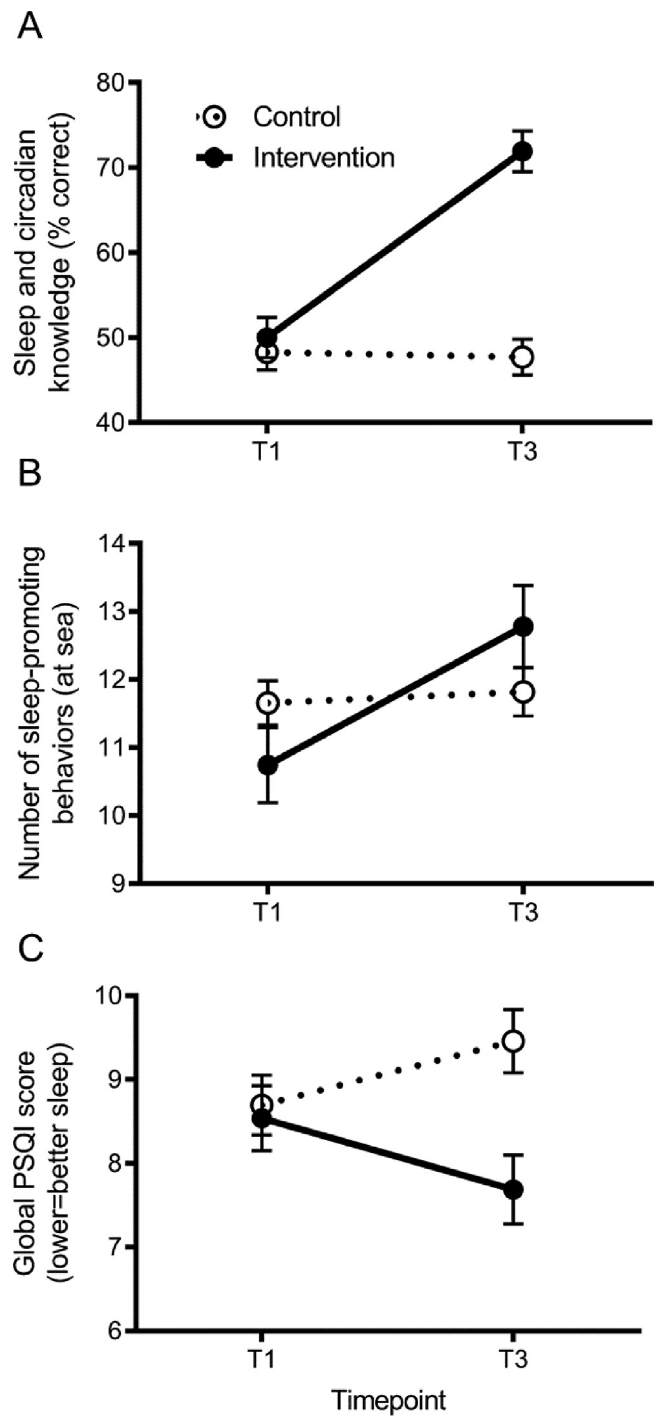

Fig. 1. The effects of the Circadian, Light, and Sleep Skills program for Shipboard Military personnel (CLASS-SM) on (A) sleep and circadian knowledge, (B) sleep-promoting behaviors, and (C) sleep quality (via Pittsburgh Sleep Quality Index [PSQI] scores). Estimated marginal means and standard errors for control (dashed lines and open circles) and intervention groups (black lines and closed circles) at T1 versus T3, controlling for age, chronotype, and gender, are plotted. T1, baseline questionnaire (intervention and control groups); T3, longer term follow-up survey administered electronically to both groups within 1 month of returning from sea, 2-4 months after T2.

Satisfaction and perceived relevance

At T2, participants reported high overall satisfaction, high relevance, and having learned something new (Table 4).

Table 2
Sleep behaviors among shipboard sailors assigned to the intervention group

	T1 *M* (*SD*)	T3 *M* (*SD*)	*P*
Getting morning light	0.58 (0.50)	0.81 (0.40)	.056
Avoiding exercise before sleep	0.57 (0.51)	0.87 (0.34)	.031*
Limiting caffeine before sleep	0.63 (0.49)	0.89 (0.32)	.017*
Taking naps	0.75 (0.44)	0.86 (0.36)	.326
Making sleep a priority	0.92 (0.27)	0.92 (0.27)	1.000
Keeping a consistent bedtime	0.89 (0.32)	0.93 (0.27)	.663
Creating a bedtime routine	0.88 (0.33)	0.96 (0.20)	.327
Using relaxation techniques before sleep	0.56 (0.51)	0.78 (0.42)	.031*
Limiting light before sleep	0.68 (0.48)	0.96 (0.19)	.009**
Using earplugs or white noise to sleep	0.29 (0.46)	0.32 (0.48)	.745
Wearing a sleep mask	0.07 (0.27)	0.15 (0.36)	.425
Using blackout curtains or other darkening materials in sleep environment	0.96 (0.20)	0.96 (0.20)	1.000
Limiting screens before sleep	0.79 (0.42)	0.86 (0.36)	.490
Using the bed for sleep and sex only	0.77 (0.43)	0.92 (0.27)	.103
Avoiding alerting activities before sleep	0.70 (0.47)	0.96 (0.19)	.017*
Making the sleeping environment comfortable	0.86 (0.36)	0.89 (0.31)	.663
Behavior sum score	10.68 (3.07)	12.61 (3.15)	.017*

CLASS-SM, Circadian, Light, and Sleep Skills program for Shipboard Military personnel; M, mean; SD, standard deviation; T1, baseline questionnaire (intervention and control groups); T3, longer term follow-up survey administered electronically to both groups within 1 month of returning from sea, 2-4 months after T2.
Paired *t* tests are for individuals in the intervention group for behaviors at sea at T1 vs T3 (n = 29).
* $P < .05$.
** $P < .01$.

Mental health outcomes

Symptoms of depression, anxiety, and PTSD were comparable between groups at baseline (see Table 1). Additional analyses were conducted to determine whether sleep quality (global PSQI) mediated the relationship between intervention participation and symptoms of depression, anxiety, and/or PTSD. Results were similar across the three symptom types. In each model, intervention participation was positively associated with sleep quality ($P < .001$; Fig. 2) but not directly with any of the psychological health symptoms ($P > .05$). However, the relationship between sleep quality and each of the 3 psychological health outcomes was significant (Boot 95%CI for depression = 0.552-1.023, $P < .001$; anxiety = 0.348-0.845, $P < .001$; and PTSD = 0.340-2.067, $P < .01$). A substantial degree of variance in psychological health was accounted for by the predictors (depression: $R^2 = 0.476$, anxiety: $R^2 = 0.427$, and PTSD: $R^2 = 0.343$). The indirect effect of sleep quality on each psychological health outcome was tested using a percentile bootstrap estimation approach with 5000 samples, and results indicated the indirect coefficients were significant (Boot 95%CI for depression = −2.373-0.615, anxiety = −1.944-0.391, and PTSD = −4.356-0.503).

Discussion

In this study, we showed that participation in CLASS-SM—a novel, brief, sleep-focused educational program—significantly improved overall sleep knowledge, sleep-promoting behaviors, sleep quality, and consequently, mental health outcomes, among shipboard sailors. Our study further demonstrated the need for a military sleep education program, and the value of CLASS-SM is evident. At baseline, neither study group answered more than half of the knowledge questions correctly; however, knowledge scores increased significantly at both follow-up time points in the intervention group. These results indicate that sailors may lack a clear understanding of the factors that can influence their sleep and circadian health, but that knowledge can be increased and maintained through minimal instruction.

Table 3
PSQI components by CLASS-SM group

Component	Group	N	T1 M(SEM)	T3 M(SEM)	Effects	F(df)	p
Sleep quality	Control	79	1.40(0.07)	1.52(0.08)	Group × Time	7.75(1, 140)	.006**
	Ix	66	1.50(0.07)	1.26(0.09)	Group	0.70	.41
					Time	1.01	.32
					Time × Age	4.08	.045*
Sleep latency	Control	78	1.59(0.10)	1.78(0.10)	Group × Time	4.62(1, 139)	.033*
	Ix	66	1.60(0.11)	1.44(0.11)	Group	1.72	.19
					Time	5.02	.027*
					Time × MEQr	4.62	.033*
Sleep duration	Control	78	1.92(0.10)	1.78(0.10)	Group × Time	2.28(1, 139)	.13
	Ix	66	1.72(0.10)	1.34(0.11)	Group	6.64	.011*
					Time	1.82	.18
					Age	5.29	.023*
					Time × Age	6.01	.015*
Sleep efficiency	Control	78	0.68(0.12)	1.17(0.12)	Group × Time	8.56(1, 137)	.004**
	Ix	64	0.84(0.13)	0.63(0.14)	Group	1.91	.17
					Time	1.01	.30
Sleep disturbance	Control	78	1.49(0.06)	1.60(0.07)	Group × Time	2.43(1, 139)	.12
	Ix	66	1.38(0.07)	1.33(0.08)	Group	4.94	.028*
					Time	0.02	.91
					Age	4.57	.034*
Sleep medication	Control	79	0.37(0.09)	0.46(0.10)	Group × Time	0.03(1, 139)	.86
	Ix	65	0.31(0.10)	0.42(0.11)	Group	0.14	.71
					Time	0.45	.51
					MEQr	4.69	.032*
Daytime dysfunction	Control	77	1.26(0.08)	1.20(0.08)	Group × Time	0.01 (1, 137)	.94
	Ix	65	1.28(0.09)	1.23(0.09)	Group	0.06	.81
					Time	0.98	.33
					MEQr	4.64	.033*

CLASS-SM, Circadian, Light, and Sleep Skills program for Shipboard Military personnel; *df*, degrees of freedom; *F*, F distribution; Ix, Intervention; *M*, mean; MEQr, reduced version of the Morningness–Eveningness Questionnaire; PSQI, Pittsburgh Sleep Quality Index; *SEM*, standard error of measurement; T1, baseline questionnaire (intervention and control groups); T2, immediate follow-up questionnaire for intervention group after CLASS-SM presentation; T3, longer term follow-up survey administered electronically to both groups within 1 month of returning from sea, 2–4 months after T2. Means are estimated marginal means from model. Group, time, and their interaction are shown for each component. Only significant covariates and their interactions are shown; all other $P > .05$.
* $P < .05$.
** $P < .01$.

Beyond knowing more about sleep and circadian health, CLASS-SM participants reported increases in sleep-promoting behaviors that were taught in the program. While prior research raises concerns about potential environmental barriers to healthy sleep in operational settings, such as noise or light,[26,38] our findings suggest service members may be able to mitigate some, though not all, of those disruptions through relatively simple behavioral changes. It is also worth noting that motivation to improve sleep health at T3 follow-up was not significantly influenced by participation in the program; however, this may be because baseline levels of motivation were already high in both groups. Interestingly, variability appeared to increase slightly at T3, perhaps reflecting differential effects of the underway period. Such high levels of motivation were likely critical to the behavioral changes reported and are consistent with prior studies that suggest service members may welcome sleep education interventions.[39] The overall positive feedback participants provided about the CLASS-SM program also suggests that to be true.

Table 4
CLASS-SM participant satisfaction and perceived relevance

	N (%) or M (SD)
Satisfaction (1-7, *M*)	
Program overall	6.34 (0.79)
Program content	5.11 (1.02)
Time spent on each topic	4.75 (1.12)
Program format	4.83 (1.03)
Relevance (1-7, *M*))	
Information on sleep	6.35 (0.90)
Information on circadian rhythms	6.16 (0.87)
Tips for improving sleep	6.41 (0.78)
Learning	
Learned something new	90.5%
Plan to use something learned	100.0%
Plan to share something learned	89.0%

CLASS-SM, Circadian, Light, and Sleep Skills program for Shipboard Military personnel; *M*, mean; *SD*, standard deviation.
One-sample *t* tests were performed against neutral values (4 on a scale of 1-7; all $P < .001$).

Considering the high motivation to improve sleep and the increases in knowledge and sleep-promoting behaviors, it is not surprising that sleep quality improved in CLASS-SM participants. Those who did not receive the program showed the anticipated reductions in sleep quality during the underway period, in line with previous reports of deployed service members.[4] In contrast, intervention group participants demonstrated improvements in the global score, and more specifically in sleep quality, sleep onset latency, and sleep efficiency components. A central tenet of the CLASS program is focusing on sleep quality when quantity may not be improved, such as a period at sea. It is also notable that a PSQI score of >5 is indicative of poor sleep,[33] and mean PSQI scores were above that threshold for all groups at all time points. While we did not perform any analyses utilizing this cutoff, this is noteworthy, and not inconsistent with studies that indicate that sleep disruption is high in service members,[1] particularly as measured by the PSQI.[40,41] Though we cannot confirm these self-report outcomes with more objective measures, the PSQI is a validated assessment tool that has been shown to capture different dimensions of sleep than actigraphy or polysomnography.[42] Collection of objective sleep measures were attempted in this study;

Table 5
CLASS-SM program participant characteristics, by participating ship

	Total *n* (%) or mean (SD)	Intervention ship 1 (n = 38)[a]	Intervention ship 2 (n = 29)	Control ship 1 (n = 83)
Gender				
Male	124 (82.7)	34 (89.5)	21 (72.4)	69 (83.1)
Female	26 (17.3)	4 (10.5)	8 (27.6)	14 (16.9)
Age, years				
17-24	53 (35.3)	2 (5.3)***	17 (58.6)	34 (41.0)
25-29	40 (26.7)	11 (28.9)	5 (17.2)	24 (28.9)
30-39	50 (33.3)	21 (55.3)	5 (17.2)	24 (28.9)
40+	7 (4.7)	4 (10.5)	2 (6.9)	1 (1.2)
Race/ethnicity[a]				
White	62 (41.3)	18 (47.4)	9 (31.0)	35 (42.2)
Black	20 (13.3)	4 (10.5)	3 (10.3)	13 (15.7)
Hispanic	28 (18.7)	9 (23.7)	4 (13.8)	15 (18.1)
Asian	21 (14.0)	3 (7.9)	7 (24.1)	11 (13.3)
Unknown or multiple	19 (12.7)	4 (10.5)	6 (20.7)	9 (10.8)
Marital status				
Married/cohabitating	67 (44.7)	22 (57.9)**	9 (31.0)	36 (43.4)
Divorced/widowed	15 (10.0)	7 (18.4)	2 (6.9)	6 (7.2)
Never married	68 (45.3)	9 (23.7)	18 (62.1	41 (49.4)
Pay grade/rank				
E1-E3	41 (27.3)	1 (2.6)***	11 (37.9)	29 (34.9)
E4-E6	72 (48.0)	19 (50.0)	15 (51.7)	38 (45.8)
E7-E9	16 (10.7)	11 (28.9)	2 (6.9)	3 (3.6)
Officer	21 (14.0)	7 (18.4)	1 (3.4)	13 (15.7)
Education				
High school	59 (39.3)	13 (34.2)	13 (44.8)	33 (39.8)
Some college	40 (26.7)	8 (21.1)	8 (27.6)	24 (28.9)
Two-year degree	17 (11.3)	6 (15.8)	3 (10.3)	8 (9.6)
Four-year degree or higher	34 (22.7)	11 (28.9)	5 (17.2)	18 (21.7)
Chronotype				
Definitely morning type	6 (4.0)	2 (5.3)	2 (6.9)	2 (2.4)
Moderately morning type	52 (34.7)	19 (50.0)	9 (31.0)	24 (28.9)
Neither type	77 (51.3)	13 (34.2)	13 (44.8)	51 (61.4)
Moderately evening type	14 (9.3)	4 (10.5)	5 (17.2)	5 (6.0)
Definitely evening type	1 (0.7)	0 (0.0)	0 (0.0)	1 (1.2)
Depression symptoms (mean)				
T1	6.73 (4.62)	5.55 (3.46***	10.31 (5.93)	7.04 (4.84)
T3	7.35 (5.07)	4.56 (3.78)***	9.82 (5.20)	7.78 (5.02)
Anxiety Symptoms (mean)				
T1	5.72 (4.70)	4.53 (4.02)***	8.86 (5.33)	6.13 (4.95)
T3	5.97 (5.02)	3.81 (4.52)***	7.35 (4.74)	6.50 (5.09)
PTSD symptoms (mean)				
T1	15.77 (16.01)	10.87 (11.69)***	24.27 (17.31)	17.67 (16.93)
T3	15.76 (16.48)	8.80 (12.63)***	23.57 (17.54)	16.18 (16.49)
Sleep knowledge (Percentage correct, mean)				
T1	49.0 (19.1)	53.0 (18.2)	46.8 (21.2)	48.0 (18.7)
T3	58.5 (22.7)	75.5 (15.2)	67.9 (20.7)	47.3 (19.8)
Global PSQI (Mean)				
T1	8.59 (3.16)	8.55 (3.27)	9.14 (3.75)	8.41 (2.90)
T3	8.66 (3.38)	6.94 (3.47)	8.59 (3.02)	9.54 (3.15)
Sleep Motivation (Mean)				
T1	4.09 (0.55)	4.03 (0.68)	4.13 (0.51)	4.12 (0.49)
T3	3.84 (1.82)	4.07 (0.67)	3.45 (2.85)	3.88 (1.72)XXX

[a] Asterisks indicate results of comparison tests between the to intervention ships.
* <.05.
** <.01.
*** <.001.

however, logistical factors, including operational issues and the COVID-19 pandemic, prevented us from doing so in a systematic, comprehensive manner. While future work should follow up with more objective measures if possible, the positive findings observed here across a multitude of outcomes support the validity of the results, despite the known biases associated with the use of subjective assessments (eg, social desirability bias). Further, increases in subjective sleep quality are not unimportant and may serve to reinforce sleep-promoting behaviors and reduce stress.

In addition to the direct positive influence of CLASS-SM participation on sleep quality, exploratory analyses identified an indirect relationship between participation and symptoms of PTSD, depression, and anxiety, such that greater sleep quality at follow-up was associated with better psychological health. These findings are consistent with known associations between sleep and psychological health[17,18,43] as well as a recent meta-analysis, which showed that interventions that improved sleep also resulted in better mental health outcomes.[17] Increased sleep quality at follow-up and its association with better psychological health after CLASS-SM participation has important implications because stigma surrounding mental health is often elevated in military populations and can prevent individuals from seeking treatment.[44] Unfortunately, delays in treatment lead to poorer outcomes, a devastating phenomenon, given the high rates of mental health issues and suicide across the forces.[45] While

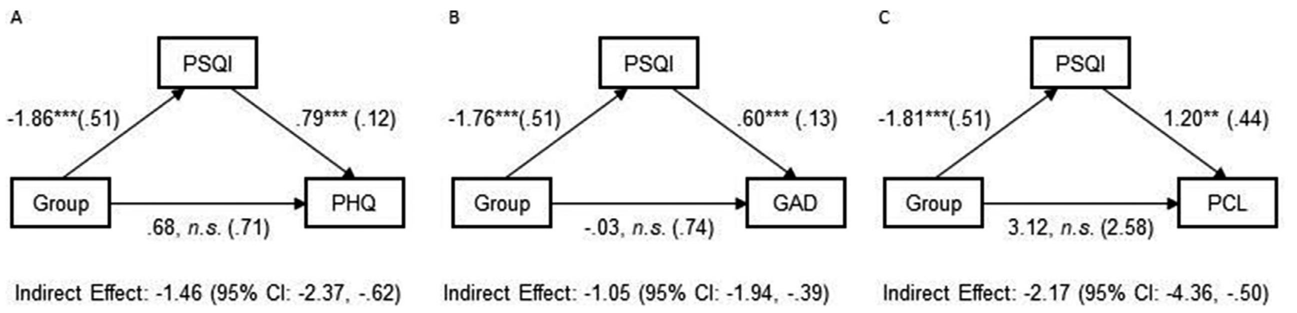

Fig. 2. Schematic diagrams of mediation analysis results showing the mediating effects of sleep on symptoms of (A) depression, (B) anxiety, and (C) post-traumatic stress (all measured at T3). Pittsburgh Sleep Quality Index (PSQI) = global sleep quality scores, Patient Health Questionnaire (PHQ) = depression symptoms, generalized anxiety disorder scale (GAD) = anxiety symptoms, and PTSD Checklist for DSM-5 (PCL) = posttraumatic stress symptoms. CI, confidence interval. Significance levels: $^{**}P < .01$, $^{***}P < .001$, n.s., nonsignificant ($P > .05$).

military culture leads many to think of sleep loss as "a badge of honor,"[3,20] service members still may be more likely to engage in a program that highlights sleep rather than one focused on psychological health. Thus, offering sleep health programs such as CLASS-SM may be a strategy to address mental health issues in a less overt way.

This study had many strengths, including the quasi-experimental design and months-long follow-up period in a reasonably large sample of sailors during an underway period. However, several limitations must be noted. Certain participant characteristics differed between study groups (age, chronotype, rank). While multivariable analyses controlled for these characteristics, the lack of equivalent groups could have introduced bias. The intervention group had more morning types, who are typically less vulnerable to poor sleep and mental health outcomes.[2] On the other hand, sleep issues tend to increase with age.[46] Considering the intervention group had more early chronotypes and were older in age (2 factors that often correlate with one another), these effects may have simply canceled one another; however, given the somewhat limited range of both in this sample (7 individuals over age 40 and 6 classified as "definitely morning" chronotype), it is unlikely that this affected outcomes in any meaningful way. In future studies with larger sample sizes, focused analyses could be conducted to compare intervention effects by chronotype, which represents an under-explored factor within this population.[2] It is also possible that undiagnosed or unreported sleep disorders were present in our population, given that we relied on self-report to exclude study volunteers on this basis. In addition, attrition was 49.7%. While similar attrition is commonly observed in longitudinal military research,[23,24,47] it may reduce the generalizability of the results, particularly because more high-ranking sailors completed all time points. Similarly, more high-ranking sailors were included in the intervention group. High-ranking sailors may have different experiences and duties onboard ships than lower-ranking sailors (eg, less crowded sleeping areas), which could lead to differences in their ability to make changes to their sleep-related behaviors; future studies should explore differences in factors that influence shipboard sleep by rank and job.[40] Another threat to generalizability is the unique sample of shipboard sailors; it is likely that the characteristics, experiences, and needs of service members differ across the military branches and even between various classes of ships.

Conclusions

Military service members are expected to live and work under conditions that often impede sleep, which adversely impacts performance and health. The results of this study demonstrate that a relatively brief education program such as CLASS-SM can improve sleep health at sea, and that improving sleep may also enhance psychological health outcomes.

Data availability statement

The datasets generated and/or analyzed during the current study are not publicly available due to security protocols and privacy regulations, but they may be made available on reasonable request to the Naval Health Research Center Institutional Review Board (contact phone +1 619 553 8400).

Disclaimer

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Declaration of Competing Interest

None.

Acknowledgments

We are grateful to the service members, veterans, and scientists who provided feedback on formative stages of the program, in particular "Docs" Bradley Kowitz and Patrick Nardulli, and colleagues Robyn Martin Englert and Cynthia Simon-Arndt; to Dr. Dale Russell, LT Brian Deadmon, CDR Mark Hardzinski, and CAPT Bud Couch for facilitating study participation of the two destroyers; to the research assistants and others who assisted with data collection and processing, including Jessamyn Boltz, Sarah Carinio, Bianca Colon, Kathrine Haluch, Lauren Hurtado, Jourdan Jackson, Vanessa Perez, and Dr. Jayson Rhoton; and to Dr. Jennifer Belding for her assistance with visualizations of the mediation analyses.

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