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Original Article

Work–rest pattern, alertness and performance assessment among naval personnel deployed at sea: A cross sectional study

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ABSTRACT

Background: The combat naval vessels require continuous operational preparedness for guarding the vast coastline. Sailors onboard these ships are at risk for sleep deprivation. Sailors may be vulnerable to chronic fatigue; and decreased performance, vigilance, and cognitive functioning owing to sleep debt, which may affect safety during tactical operations and while transportation of ships. In this study we assessed the work–rest pattern and level of alertness during sailing and non sailing days.

Methods: Thirty-two male participants maintained a 24-h sleep and activity log for 5 days. Furthermore, qualitative gross motor activity was recorded using an actiwatch during these 5 days. Participants also completed four test sessions of personal digital assistant (PDA) based psychomotor vigilance task (PVT) test: pre-sleep, post-sleep, pre-work, and post-work. A comparison of data was performed using the Wilcoxon signed-rank test.

Results: Sailors received approximately 1 h less of rest while sailing. There was a significant difference in bedtime, wake-up time, total sleep time, sleep onset latency (SOL), wake up after sleep onset (WASO), and the number of awakenings during the non-sailing and the sailing days. PVT data showed significantly higher reaction times during the sailing days on pre-work and post-sleep sessions.

Conclusion: Our study shows that although the sailors are not getting sufficient restorative sleep while sailing as compared to non-sailing days, this is not affecting their cognitive functioning while working.

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Introduction

Adequate sleep is essential for maintaining good physical health and mental alertness. Modern lifestyle and job requirements entail varying degree of sleep restriction in young adults. Sailors onboard combat ships of the Indian Navy are at risk for sleep deprivation. Guarding the vast coastline of 7517 km, these vessels require continuous operational preparedness. Sailors go through sleep disturbance due to the changes in the time zone, and crowded sleeping places, besides overtime duties during off working hours, and rotating shift.^{1,2}

Altered work-rest schedules lead to cumulative sleep loss and circadian de-synchronization.³ As sleep debt accumulates, a person's mood, short-term memory, attention, motivation, alertness, situational awareness, task performance, and physical performance will be affected.⁴ Furthermore, sleepiness at work, chronic fatigue, and decreased vigilance may affect safety during tactical operations and while maneuvering ships.^{5,6} The psychomotor impairment due to sleep deprivation increases the risk for accidents related to human errors.

Modern technologies can objectively assess the level of alertness and sleep parameters. The personal digital assistant (PDA)-based psychomotor vigilance task (PVT) is a standard tool used for the objective assessment of performance, vigilance, and cognitive functioning in various field conditions.⁷ It measures sustained or vigilant attention by recording reaction times (RT) to visual or auditory stimuli that occur at random intervals.⁸ Actigraphy is a sleep assessment tool used extensively in the field of sleep research.⁹ It is based on the principle of difference in movements during asleep and awake states.¹⁰ The use of actigraphy in field conditions is advantageous compared to traditional polysomnography (PSG) as it is less expensive, non-invasive and can conveniently record sleep data for days, or even weeks.¹¹

Operational efficiency for the Navy heavily rests on alertness and quick responses of its sailing team. There is a lack of data from India related to fatigue and its effect on mental alertness levels in sailors involved in a combat role. Therefore, the primary objective of this study was to assess and compare sailors' work-rest pattern and level of alertness during sailing and non-sailing days. In addition, we compared the "duration of sleep" data as recorded in the sleep diary with the actigraphy sleep data.

Material and methods

Study setting and participants

The study was conducted onboard a large Indian Naval Ship. Fifty healthy naval personnel from different ranks, duration of service, departments, and watch-stations participated in the study. Individuals with a history of psychiatric illness, such as depression or sleep disorders, were excluded from the study. Other exclusion criteria were chronic smoking habit, a history of alcoholism, those who reported sick, or had consumed any medications causing drowsiness over the past 48 hrs. Newly

inducted sailors were also excluded, only those with at least five years of service were enrolled.

The study was approved by the institutional ethics committee. Each participant was enrolled after obtaining written informed consent for continuous recording of their work-rest pattern. The study did not interfere with their individual routines.

Data collection

The sleep data collection for each individual was performed for five consecutive days, both when ashore and during sailing. The data were collected from each participant at different durations of sailing for afloat (sailing) data and prior to sailing for ashore (non-sailing) data due to the operational commitments of each individual. Moreover, limited availability of actiwatches did not allow simultaneous recording of sleep data for all 50 participants. Though the participants were involved in shift work during sailing phase, the data was collected continuously for 05 days when they were in day shifts only.

Heart rate (HR) and blood pressure (BP) were measured using a BPL multi parameter monitor MPM 5633 between 1000 h and 1100 h on each day during both phases (i.e. sailing and non-sailing days) on the right upper arm in the sitting position.

Ambient temperature on the ship was measured using a wet bulb globe thermometer (AFLIR company, HT 30). The average room temperature was $29.4 \pm 1^\circ\text{C}$ with 70% relative humidity.

Daily sleep diary and daily activity log: Each participant was provided with a sleep diary for recording sleep for five days. Participants also recorded a 24-h activity log for five days to establish cumulative sleep debt during that period.

Sleep data collection by actigraphy: A Philips Respironics Inc. Actiwatch (with software provided) was used in this study. The actiwatch is a non-invasive, ambulatory, wearable device similar to a wristwatch. It utilizes an accelerometer with a sensitivity of less than 0.1-G force to measure the degree of activity. The sampling frequency of the actiwatch was 32 Hz. The actiwatch output was scored using Respironics software. All participants were instructed to wear the actiwatch continuously on their non-dominant wrist for five days of data collection. If participants removed the watch, they were instructed to mark that event in their daily activity log book. The primary outcome measure was total sleep time (TST). Secondary outcomes measured by the actiwatch were sleep onset latency (SOL), wake up after sleep onset (WASO), and sleep efficiency (SE). SOL indicates how long it took them to fall asleep, WASO indicates the total amount of time that subjects were awake due to sleep disruption between first falling asleep and finally waking up, and SE (%) indicates the actual sleep time expressed as a percentage of time in bed. The actigraphy data was analyzed in 1-min epochs.

Psychomotor vigilance task (PVT) test: reaction time (RT) was assessed using the PVT-192 (Ambulatory Monitoring Inc., Ardsley, NY). The LED display of PVT device was used to initiate a visual reaction time (RT) stimulus. During the task, each subject focused on the screen. At random intervals, a millisecond counter started to scroll, and subjects had to press a key to stop the counter as quickly as possible. After pressing

the key, the counter displayed the reaction time. Inter-stimulus intervals ranged randomly from 2 to 10 s, and the task lasted for 5 min. The average reaction time was expressed in milliseconds.

(a) Study phase 1 ashore (non-sailing) data: The qualitative gross motor activity of each individual was recorded by using Actiwatch. Additionally, each subject was instructed to maintain daily sleep diary and activity log for five consecutive days to establish cumulative sleep debt during that period. Each participant also completed four test sessions of PVT per day, which were as follows: pre-sleep, post-sleep, pre-work, and post-work. Participants completed the pre-sleep and post-sleep sessions approximately 15 min prior to bedtime and within 15 min of waking up, respectively. The pre-work and post-work PVT was performed at the beginning and end of the workday, respectively.

(b) Study phase 2 afloat (sailing) data: The same procedure was followed and the data collection was started 48 h after sailing to wean off the ashore effects, if any. On work days, participants completed the pre-work and post-work sessions within 1 h of check-in and check-out of their duties, respectively.

Statistical analysis

Descriptive statistics were used to summarize the baseline demographic characteristics of sailors participating in the study. The comparison of the sailors' clinical parameters ashore (non-sailing) and afloat (sailing) was performed using the Wilcoxon signed-rank test. The statistical analysis was performed using SPSS software version 17.

Results

Out of 50 participants, only 32 participants completed both phases of the study. Ten individuals left the study due to

administrative reasons, and eight could not complete the study due to emergency leaves, sickness while afloat, and failure to complete the activity log. The mean ($\pm$ SD) age, weight, and height of study participants were 30.8 ± 7.7 years, 73.5 ± 7.3 kg, and 171.3 ± 7 cm, respectively.

Basal heart rate and blood pressure: Comparison of basal heart rate and blood pressure during non-sailing and sailing days is shown in Table 1.

There was a statistically significant increase in the basal heart rate as well as the blood pressure observed while sailing. However, this increase in BP (2 mm of Hg) and HR (3 beats/min) may not be clinically relevant.

Daily activity log and work-rest pattern with sleep diary: Each participant was instructed to maintain a record of actual duration of sleep while sailing and at shore. The results are summarized in Table 2.

The results indicate a significant difference in total sleep time and awake hours during non-sailing and sailing days. During sailing, sailors received approximately 1 h less rest.

Actigraphy: According to the actigraphy data shown in Table 3, there was a significant difference in bedtime, wake up time, total sleep time, SOL, WASO, and number of awakenings during non-sailing and sailing days. Similar to the results obtained based on the sleep diary, the actigraphy recording showed that bedtime was later and wake-up time was earlier during sailing days, thereby reducing the total duration of rest.

Correlation between sleep diary and actigraphy data: There was a positive correlation between the sleep diary data and the actigraphy data regarding bedtime, wake-up time, and total sleep time, but no correlation was found between the quality of sleep recorded in the sleep diary and sleep efficiency, as shown in Table 4.

Psychomotor vigilance test: The PVT data showed significantly longer reaction times during sailing on pre-work and post-sleep tests, as shown in Table 5.

Table 1 – Basal heart rate and blood pressure during non-sailing and sailing days.

S no.	Parameter	Non-sailing (Mean $\pm$ SD)	Sailing (Mean $\pm$ SD)	p value
1	Heart rate (beats per min)	73 $\pm$ 8	76 $\pm$ 7	0.00
2	Systolic BP (mm of Hg)	124 $\pm$ 8	126 $\pm$ 7	0.01
3	Diastolic BP (mm of Hg)	74 $\pm$ 5	76 $\pm$ 6	0.04

Table 2 – Comparison of activity log and work rest pattern by sleep diary during non-sailing and sailing days.

S. no.	Questionnaire	Non-sailing	Sailing	p value
1	At what time did you go to bed (h)	22.15 $\pm$ 0.39	22.33 $\pm$ 0.48	–
2	After settling down, how long did it take you to fall asleep (min)	6.54 $\pm$ 3.65	12.28 $\pm$ 5.40	0.00
3	After falling asleep, how many times did you wake up in the night	0.78 $\pm$ 0.60	2.85 $\pm$ 1.23	0.00
4	At what time did you finally wake up (h)	5.42 $\pm$ 0.50	5.12 $\pm$ 0.36	–
5	At what time did you get up (h)	5.54 $\pm$ 0.54	5.29 $\pm$ 0.42	–
6	How long did you spent in the bed last night (from first getting in to finally getting up) (h)	7.24 $\pm$ 0.51	6.36 $\pm$ 0.67	0.00
7	How do you rate the quality of you sleep last night 1, 2, 3, 4, 5	3.91 $\pm$ 0.58	2.41 $\pm$ 0.66	0.00
8	Total rest in hours	7.24 $\pm$ 0.51	6.36 $\pm$ 0.67	0.00
9	Rest %	31.34 $\pm$ 2.28	28.42 $\pm$ 3.47	0.00
10	Wake hours	16.07 $\pm$ 0.58	16.41 $\pm$ 0.92	0.00
11	Wake %	68.12 $\pm$ 2.67	71.53 $\pm$ 4.15	0.00

Table 3 – Comparison of Actigraphy results during non-sailing and sailing days.

S. no.	Actigraphy results	Non-sailing (mean $\pm$ SD)	Sailing (mean $\pm$ SD)	p value
1	Bed Time (h)	22.09 $\pm$ 0.43	22.41 $\pm$ 0.50	–
2	Get up time (h)	5.52 $\pm$ 0.56	5.18 $\pm$ 0.46	–
2	Time in bed	7.22 $\pm$ 0.50	6.20 $\pm$ 0.78	0.00
4	Total sleep time	7.00 $\pm$ 0.87	6.15 $\pm$ 0.87	0.00
5	Sleep onset latency	17.52 $\pm$ 5.34	24.27 $\pm$ 5.49	0.00
6	WASO (min)	27.30 $\pm$ 7.25	34.54 $\pm$ 9.45	0.00
7	No of awakenings	12.62 $\pm$ 6.68	26.53 $\pm$ 6.56	0.00
8	Sleep efficiency	84.16 $\pm$ 2.64	64.26 $\pm$ 13.50	0.00

Table 4 – Correlation between sleep diary and actigraphy data.

S. no.	Data	Sleep diary data	Actigraphy data	Pearson correlation (r)	p value
1	Time to go bed (non-sailing)	22.15 $\pm$ 0.39	22.09 $\pm$ 0.43	0.93	0.00
2	Time to go bed (sailing)	22.33 $\pm$ 0.48	22.41 $\pm$ 0.50	0.79	0.00
3	Wake up time (non-sailing)	5.54 $\pm$ 0.54	5.52 $\pm$ 0.56	0.93	0.00
4	Wake up time (sailing)	5.12 $\pm$ 0.36	5.18 $\pm$ 0.46	0.75	0.00
5	Total sleep (non-sailing) (h)	7.24 $\pm$ 0.51	7.00 $\pm$ 0.87	0.41	0.01
6	Total sleep (sailing) (h)	6.36 $\pm$ 0.67	6.20 $\pm$ 0.78	0.70	0.00
7	Sleep efficiency/quality (non-sailing)	3.91 $\pm$ 0.58	84.16 $\pm$ 2.64 (%)	0.13	0.47
8	Sleep efficiency/quality (sailing)	2.41 $\pm$ 0.66	64.26 $\pm$ 13.50 (in %)	0.12	0.40

Table 5 – Psychomotor vigilance data.

Reaction times (ms)	Non sailing (mean $\pm$ SD)	Sailing (mean $\pm$ SD)	p value
Pre-work	238 $\pm$ 20	265 $\pm$ 60	0.01
Post-work	274 $\pm$ 40	279 $\pm$ 30	0.20
Pre-sleep	275 $\pm$ 30	277 $\pm$ 20	0.70
Post-sleep	232 $\pm$ 20	258 $\pm$ 20	0.00

Discussion

Peacetime mishaps with Naval warship due to multiple factors, such as human error, suboptimal maintenance etc., adversely affects maritime capabilities of any country. The psychomotor impairment due to inadequate sleep in rough sea increases the risk for accidents related to human errors. To the best of our knowledge, this is the first attempt to study work-rest patterns of Indian Navy sailors and its effect on sustained vigilance activity. Prior studies on sleep deprivation due to shift-work have reported inconsistent results on cognitive functions. Olsen et al. showed that sleep debt may obstruct planning and preparations in maritime operations, which in turn increase the risk for accidents and fatal errors.¹² Matsangas et al. indicated that harsh motion affect sleep quality resulting in significantly increased duration of sleep in rough seas as compared to calmer sea conditions.¹³ A report by Houtman et al. concluded that fatigue may be a causal factor in 11–23% of the collisions and groundings in shipping, but the relationship between the shift system and fatigue was inconclusive.¹⁴

In this study we recorded work rest pattern of the crew onboard a large naval vessel by actigraphy and sleep diary. The physiological parameters recorded during voyage indicated statistically significant rise in basal heart rate (HR) and blood

pressure (BP) during sailing, when compared to non-sailing days. This difference in basal HR and BP may be attributed to anxiety associated with harsh working conditions during sailing.

Subjective determination of sleep adequacy by personal sleep diary data showed significantly lesser duration while sailing as compared to non-sailing days. The lack of restorative sleep while sailing in our participants is ascribed to changing time zones, unconventional working hours, hazardous working conditions, harsh environments, crowded sleeping spaces, etc. A study by Philips also concluded that a work environment on board ship is not very conducive to obtaining sufficient restorative sleep.¹

The actigraphy data corroborated with sleep diary. It indicated delayed bedtime and early wake-up time during sailing. Sleep efficiency was also significantly lower during sailing days indicating inadequate restorative sleep. Such chronic sleep deprivation may lead to sustained attention deficit. The actigraphy data indicated higher episodes of awakenings while sailing as compared to non-sailing days. A prior British study showed that weekly changes in watch schedules caused disrupted sleep in watch keepers. The likely mechanism of sleep deprivation is the inability of the internal body clock to adapt rapidly to abrupt changes in the watch schedule.¹⁵

The reaction time assessed by PVT is extremely sensitive to effects of sleep deprivation.¹⁶ The PVT is a practical and objective tool for identifying sailors with impaired vigilance. Optimal performance on PVT relies on activation of both the sustained attention system and motor system of the body. Poor performance results from disengagement from the task due to lack of attention.¹⁷ Sleep deprivation severely compromises the reaction time to respond to a stimulus, resulting in accidents or near-fatal events.^{5,18}

In our study, significant differences in the levels of alertness were observed when a sailor is at rest on land and during pre-work and post-sleep periods while sailing. The mean reaction times post-work and pre-sleep were higher during sailing days; however, the difference was not significant. The decrease in alertness during pre-work and post sleep state indicates that the individual is not getting adequate restorative sleep at night during sailing but it is not affecting the individual's cognitive functioning during work. This may be attributable to the regular training and preconditioning of sailors before sailing. Furthermore, all the participants in the study were used to the working conditions of sailing with at least five years of experience. Sleep requirements and the level of mental alertness after prolonged work vary from individual to individual. A study by Goel et al. showed robust differences among individuals in terms of their degree of cognitive vulnerability to sleep loss, which are related to their genetic composition.¹⁹

The findings of this study should be considered in light of certain limitations. Firstly, self-reported data is subjected to recall bias and therefore not be a valid measure of actual sleep period. Furthermore, the sleep log and actigraphy assess different components of sleep; the sleep log is based on recollection of sleep and the actigraphy records motor activity.²⁰ Since different outcomes are expected, we measured the sleep by a subjective method (i.e. sleep diary) and an objective method (i.e. actigraphy). In our study, the actigraphy data corroborated with sleep diary data, as positive correlation was observed in terms of time of initiation of sleep, wake-up time, and total sleep time. There was no significant correlation between the sleep score based on the sleep diary and sleep efficiency based on actigraphy results. A similar study by Harris et al. also showed lack of correlation between objectively derived sleep indices and the self-reported measure of sleep quality and strong inter-relationships among the subjectively derived sleep indices, such as between self-reported sleep quality and sleep efficiency.²¹

Polysomnography (PSG) is a gold standard for conducting sleep studies. Although we have not used PSG for the sleep study, some studies show a close correlation between parameters assessed by PSG and actigraphy.^{11,15,18}

Multicentre studies with crew members from naval vessels of varying capacity need to be carried out for better generalization of results. Furthermore, the effect of systematic training programs on performance of sailors of different age groups, duration of service, and the effect of stimulants such as tea/coffee can be studied by including other tests such as polysomnography.

In conclusion, sailors, even though experiencing some sleep deprivation, are vigilant while sailing. Countermeasures

such as health education, sleep hygiene measures, and better work-rest schedules are proposed as a first step to avoid potential hazards of sleep deprivation.

Conflicts of interest

The authors have none to declare.

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