Int Marit Health
2020; 71, 4: 237–248
10.5603/IMH.2020.0042
www.intmarhealth.pl

ISSN 1641–9251

VIA MEDICA

ORIGINAL ARTICLE

Poor sleep quality, long working hours and fatigue in coastal areas: a dangerous combination of silent risk factors for deck officers on oil tankers

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ABSTRACT

Background: *The high number of marine incidents in port and coastal areas due to the tired deck officers' erroneous actions are one of the major challenges of marine transportation. Approaching, berthing, and cargo handling (ABC) are the most stressful and exhausting operations of the ship in these areas, which are carried out consecutively and uninterruptedly.*

Materials and methods: *This study examined Psychomotor Vigilance Task (PVT) performance, Arrow Flanker Task performance and the Pittsburgh Sleep Quality Index (PSQI) of 70 deck officers of ocean-going oil tankers with 4on–8off shifts at the end of the first shift of cargo-handling operations. In this case, they had worked more than 14 hours continuously. Also, their level of sleepiness was assessed using the Karolinska Sleepiness Scale (KSS) at the beginning, middle, and end of their first shift of handling operation.*

Results: *The results were analysed according to the duration at sea and deck officers rank. PSQI, KSS, PVT mean reaction times and lapses, and also Flanker's variables were higher among the chief and second officers who were present on board between 0–30 days. The state of officers who were present on board between 31 to 60 days was better than the officers with 0–30 and 61–90 days' duration at sea. In addition, the results show that sleep quality during tour of duty affects cognitive performance and sleepiness of officers during cargo handling operations.*

Conclusions: *The paper concludes by discussing possible solutions for reducing fatigue and human error among seafarers.*

(Int Marit Health 2020; 71, 4: 237–248)

Key words: deck officers, fatigue, cognitive performance, sleepiness, sleep quality, approaching, berthing, cargo handling operation, oil tankers

INTRODUCTION

Maritime transportation experts have made considerable attempts to reduce marine accidents that mostly occur in coastal areas and ports [1], but the statistics show that there has not been a considerable reduction in the number of these accidents and incidents [2–4]. Approaching port, berthing, and cargo handling (ABC) are three of the most important ship operations in the coastal water of the destination port and many accidents have occurred during these operations. The statistics suggest that almost 78% [5] and 70% [6] of maritime casualties are happening during these operations and a substantial number of them were due to the human erroneous actions especially made by the deck officers [7].

The navigation officers of ocean going oil tankers are divided into two groups of day work and shift work in the long duration of the tour of duty. The day work officer is the ship's captain who has the highest age and maritime

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experience among the navigation officers, and whose work shift is from 8.00–17.00. Moreover, the shift work officers are further divided into three groups of first officers with the work shifts (04:00 to 08:00 and 16:00 to 20:00), second officers with the work shifts (00:00 to 04:00 and 12:00 to 16:00) and third officers with the work shifts (08:00 to 12:00 and 20:00 to 24:00), where the first officers have the highest age and maritime experience among these three groups, and the second and third officers take the next places, respectively. The total work shifts of these officers form a fixed work/rest cycle [8].

Many studies have shown that one of the main problems of shift workers is their working at night and sleeping during the day which results in circadian misalignment, considerable level of fatigue, decreased cognitive performance at night, and also leads to sleepiness during both day and night shifts [9–11]. This is a problem even for deck officers who have been involved for a long time in shift working because studies show that the endogenous rhythms of less than 3% of people, who continually work night shifts, can completely adapt to the night work shifts [11, 12]. In addition, deck officers spend a lot of time in a restricted and confined environment and face some problems due to the nature of marine occupations, including sleeping in a moving and noisy environment that is constantly influenced by the vibrations of the engine room [13–15]. As a result, sleeping is continuously disturbed and restricted; restorative sleep is hindered [14, 16]. Some other outcomes resulting from the above-mentioned situation are a chronic reduction of sleep quality [17, 18], fatigue and development of sleep disorders like obstructive sleep apnoea and insomnia [19, 20].

Various definitions of fatigue have been proposed and cover a state resulting from factors such as insufficient sleep, extended wakefulness, and work/rest requirements out of sync with circadian rhythms, which possibly cause decrements in vigilance and cognitive performance [17, 21, 22]. Sleep quality is one of the influential factors in fatigue and performance [23–25] and it refers to how well individuals sleep and can include quantitative aspects of sleep like sleep latency, sleep hours, and depth of sleep [26]. Many studies have shown that one of the most important factors that affects navigation officers' performance during ship operation like cargo handling is fatigue and sleepiness [9, 27], and several marine disasters involving e.g. the Exxon Valdez, ferry MS Herald of Free Enterprise, Jambo, and Shen Neng ships were because of the tiredness of deck officers happening in coastal areas and narrow straits with heavy traffic load [28–30].

Several weeks after the start of the tour of duty and passing through seas and canals, vessels usually reach coastal and approach areas in order to perform cargo handling operation [27]. Navigation officers, who are suffering from the above mentioned problems, start conducting ship operations in these areas. In the operations in coastal areas and ports, deck officers face more restrictions and difficulties than in open seas because of heavy traffic load and congested waters [27]. Generally, the procedure, which is followed to increase the safety as well as the efficiency of the approaching operations, is as follows: the officers of the previous shift participate in the first 2 hours of the present shift while the watch-keeping officers of the next shift take part in the last 2 hours of the current shift. As a result, the rest hours decrease while the workload of officers increases [27]. Immediately as the approaching operation finishes and the vessel approaches the berth, the berthing operation begins. The berthing operation normally takes about 4 to 5 hours for oil tankers; and to conduct this operation, the first and second officers are present on the forward and aft stations of the ship along with the teams of seamen. Another team including the master, pilot, third officer, and wheelman manage the operation from the bridge. As the berthing operation completes, cargo handling operations start immediately. This operation is really stressful and mainly calculation-driven and requires high accuracy and precision. There are many different important issues, including vessel stability, environmental protection, and application of port regulations, that have to be taken into account constantly [27]. In this phase, many inspectors and auditors inspect the ship multiple times, thereby disrupting the working and resting hours of the officers. It is also worth noting that all of these steps have to be taken as quickly as possible because any loss of time can cause significant financial penalties. This issue is one of the most important reasons for fatigue and stress of deck officers during ABC operations [27, 31].

The above mentioned situations put deck officers in a lot of stressful situations for a long time, that is, 15–16 hours, with minimum rest time, and long working hours which could be considered as an important risk factor for fatigue and sleepiness [27, 32]. They must also perform several cognitive activities like arithmetic and calculation-driven tasks simultaneously while they are bombarded by a large volume of internal and external stimuli. Under such circumstances, considering the limited capacity of the human brain, the high load of mental activities exceeds the operators' mental capacity and causes mental fatigue [19, 33]. Figure 1 presents an infographic of the problems faced by the navigation officers from the beginning of the tour of duty up until the beginning of the cargo handling operation.

Long working hours and high workload could greatly affect the performance of navigation officers during the sensitive cargo handling operation which is dependent on their cognitive abilities, by increasing their fatigue and sleepiness [34]. For example, Guo et al. [35] showed that mental fatigue causes reduced response inhibition in drivers and Boksem et al. [36] has shown that fatigue can cause a sustained

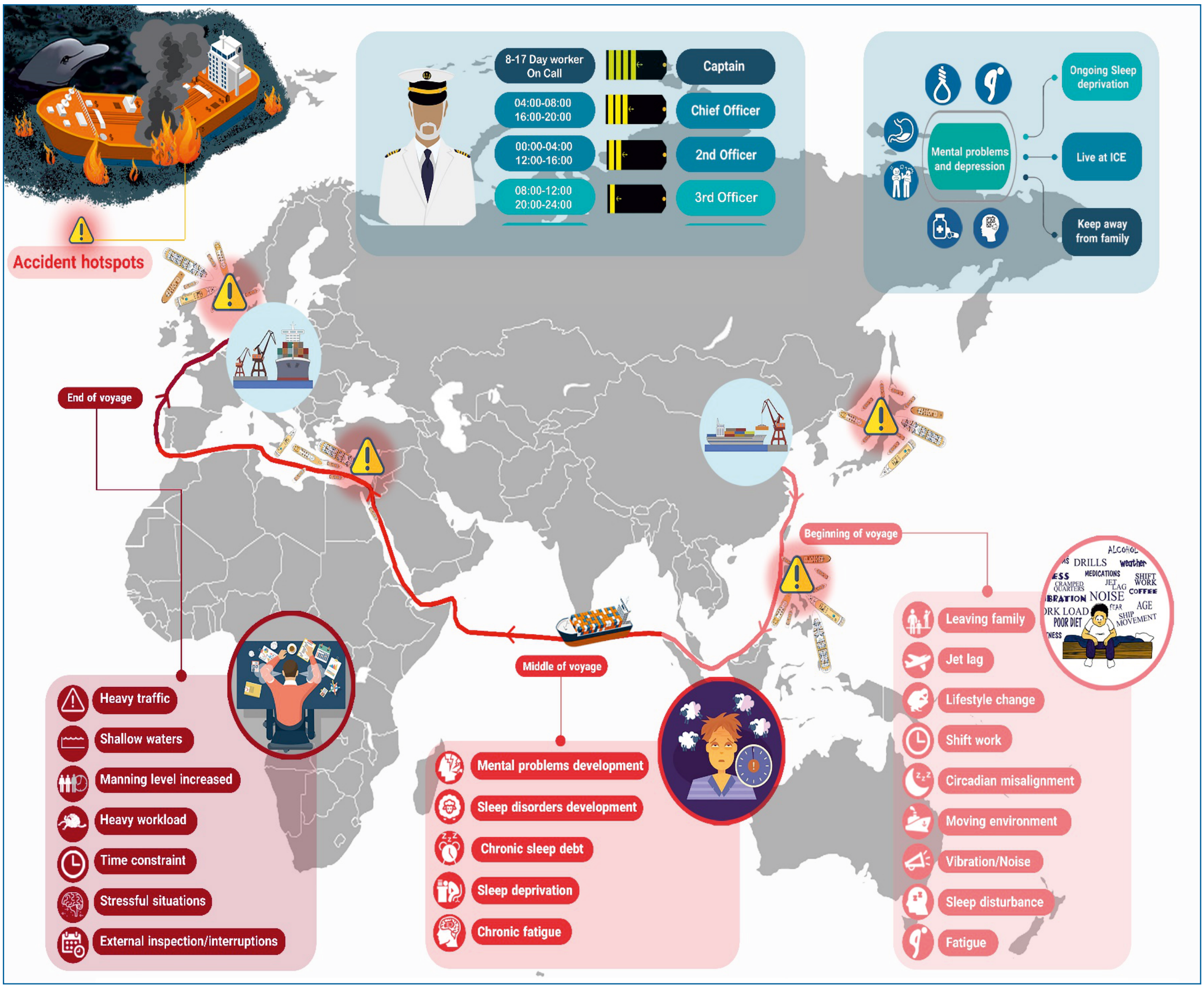

Figure 1. The infographic is a symbolic presentation of a typical voyage of ocean-going vessels from the loading port to the discharge port. During tour of duty, seafarers buckle under various difficulties in different parts of voyage that impose a high level of fatigue in them. Fatigue impairs performance during fulfillment of duties especially in congested waters with heavy traffic load like ports and coastal areas. Statistics also show that navigation officers make more errors in this areas compared with other parts of the route. In the coastal areas of the destination port, due to issues like having to increase manning level, long working hours, time constraints, poor sleep quality during the tour of duty, stressful and fatiguing duties, the risk of human error is increased. Maritime accidents bring irreparable damages to the marine environment and result in many life and financial losses.

attention deficit and lead to easy distraction. Inhibition of environmental distractions and long term attention are crucial factors during different ship operations like cargo handling, and are essential factors for correct fulfilment of complex duties and prevention of the overloading of the central information processing system. Also, it should be mentioned that fatigue and sleepiness caused by long working hours, disruption of circadian rhythms and poor sleep quality can degrade cognitive abilities like attention and vigilance with an increase in reaction time (RT) and lapses of attention, especially in activities that require precise and immediate responses [11, 23, 34, 37, 38]. Therefore, identification of the group of navigation officers with weaker performance in the sensitive operation of cargo handling could make great contributions to measures preventing the occurrence of human error.

Individuals respond to fatigue differently and may become fatigued with varying degrees of severity under the same circumstances. For instance, duration at sea may be one of the determinants of cognitive deficits, sleepiness and sleep quality [13, 39]. Besides, many studies have shown that the work pattern (shift work or routine day work) and shift schedules (night or day watchkeeping), which vary between deck officers, have an impact on fatigue [23, 34, 37]. Hence, the shift schedule and work pattern is considered to be one of the factors influencing cognitive performance and sleepiness during the cargo

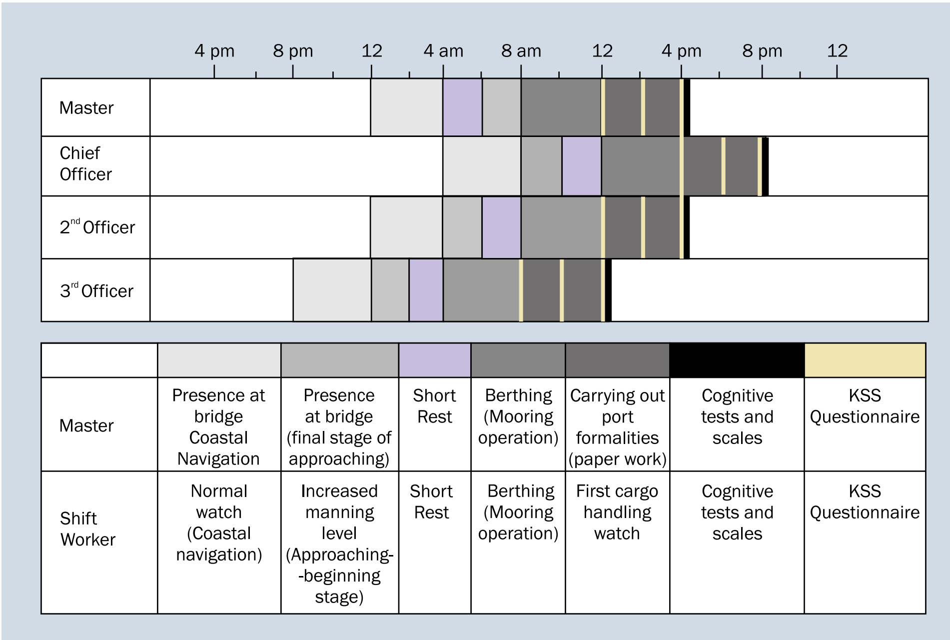

Figure 2. The working schedule of day work and shift work officers after entering into the coastal area and beginning the approaching, berthing, and cargo handling (ABC) operations. Also, the hours of night shifts are the same as day shifts; KSS — Karolinska Sleepiness Scale

handling operation and may also affect sleep quality during the tour of duty.

The present research hypotheses were as follows:

- the deck officers' rank and duration at sea affect their cognitive performance and sleepiness during cargo handling operation;
- the deck officers' rank and duration at sea affect their sleep quality during tour of duty;
- is there any correlation between the sleep quality during tour of duty and cognitive performance and sleepiness during cargo handling operation?

MATERIALS AND METHODS

DEMOGRAPHIC QUESTIONNAIRE

This questionnaire consisted of questions about the age, work and rest hours during the last tour of duty, deck officer's rank, seafaring experience, duration at sea, disease history, history of drug and alcohol abuse.

PARTICIPANTS

The current study is part of a larger project investigating the cognitive performance and sleep of navigation officers with fixed 4on/8off work shifts during the three operations of approaching, berthing, and cargo handling [27, 34].

A total of 70 mariners including masters as day workers (08:00 to 17:00) and also chief officers (04:00 to 08:00 and 16:00 to 20:00 shifts), second officers (00:00 to 04:00 and 12:00 to 16:00) and third officers (08:00 to 12:00 and 20:00 to 24:00) who were working fixed shifts 4on/8off on ocean-going vessels with gross registered tonnage > 56,000 involving cargo handling operations were selected.

Ocean-going oil tankers with gross registered tonnage > 56,000 travelling in fixed routes that have finished up at the two southern Iranian seaports for loading or unloading crude oil were studied. All participants were male, healthy, and had no history of any special disease. Caffeine use was not restricted for the purpose of the study. Participants completed written informed consent forms prior to participation in the study. The protocol was under supervision of Ethics Committee of Shiraz University of Medical Science. The study protocol was based on the standards set by the latest version of the Declaration of Helsinki.

STUDY DESIGN

The need for sleep, circadian activation, and their combined effect on cognitive performance on tasks like the psychomotor vigilance task (PVT) change during the day. It is as a function of hours of sleep, hours of wakefulness, time of the day, and current sleep debt from prior days [40]. Therefore, according to the difference between the timing of shifts among deck officers, choosing an appropriate time for data collection was very important. Only deck officers who had their work shift presented in Figure 2 were examined. According to this schedule, all officers worked 14 hours continuously with a 2-hour short rest, and all officers claimed they could not sleep during those 2 hours because they were waiting for the call from the bridge. In fact, ABC procedures were aligned at a specific time of day for all participants of the same rank, but consistently differed between ranks. Also, 16-hour wakefulness was an appropriate time for cognitive performance assessment [38]; hence, the data collection time was chosen at the end of the first cargo handling shift. Also, as they were awake for at least 10 hours, the effect of sleep inertia was not an issue.

Due to the times of sunrise and sunset in that port and the seasons of collecting data, the time window from 8am to 8pm was considered as day, and therefore it can be said that all the operators' data were gathered during the day shifts. During the evaluation of cognitive performance, participants were in a closed and quiet room without any noise or visual disturbance. This room was located away from bridge and cargo control room, and all participants were supervised by an experimenter.

COGNITIVE PERFORMANCE ASSESSMENTS

Psychomotor Vigilance Task (PVT). The psychomotor vigilance is a neurobehavioral assessment test that was performed to evaluate sustained attention between different groups of deck officers. This test has high ecological validity and reliability and many studies have shown its sensitivity to fatigue, sleepiness, and circadian misalignment [10, 40, 41]. First, each participant was piloted to get familiar with the procedure so they were instructed to use their dominant finger to show the quickest reaction to a simple visual stimulus (a red light display). Each PVT administration lasted 10 min with a random inter-stimulus interval of 2–10 s.

Arrow Flanker Task. The Flanker task assesses the individual's inhibitory control of attention or selective attention capacity by taking into account the relevant stimulus while ignoring the irrelevant stimuli [42, 43]. The Flanker task requires participants to respond quickly (inter-trial interval = 1200 ms) via a forced-choice keypress to central target arrows (< or >) flanked by either congruent (<<<<<.>>>>>) or incongruent (<<><<.>><>>) arrows. Each trial started with the presentation of a central fixation cross "+", which lasted for 1000 ms and the arrow appeared 200 ms later after the fixation cross disappeared. They were instructed that the arrows would appear rapidly, so they must react quickly to perform the task; however, it was emphasized that speed and accuracy were equally important. The whole test was 10 min with 300 trials with congruent and incongruent trials being presented randomly with equal probabilities.

KAROLINSKA SLEEPINESS SCALE (KSS)

In the present study, the KSS was used to measure the subjective level of sleepiness at a particular time during the day [44, 45]. Previous research studies have evaluated the validity and reliability of the KSS through other subjective indicators of sleepiness such as electroencephalographic, behavioural variables, etc. [44, 45]. The instrument is scored on a nine-point scale indicating 1 (very alert), 3 (alert), 5 (neither alert and nor sleepy), 7 (sleepy), and 9 (very sleepy and trying to stay awake).

SLEEP QUALITY ASSESSMENT

The Pittsburgh Sleep Quality Index (PSQI) was selected to examine subjective sleep quality [26]. This 19-item questionnaire was developed to analyse the sleep quality of the respondents over the last month. The PSQI consists of self-rated questions and differentiates "poor" from "good" sleep by measuring seven domains: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction over the last month. Each element was scored from 0 to 3 and then summed into a global PSQI-score. Scores exceeding five indicate low sleep quality [26]. The PSQI has previously been validated with satisfactory validity and reliability [46].

DATA ANALYSIS

IBM_SPSS_Statistics 23 (2014) was used to perform statistical analyses. In the PVT, RT was measured as the time between the onset of the red circle and the first keypress. Based on previous research on PVT [47], the following outcome measures of PVT performance were included: 1) mean RT, 2) number of lapses, defined as RT > 500 ms (errors of omission). In the Flanker task, response time was measured as the time between the onset of the arrow and the first keypress. Response accuracy and number of errors were calculated as the percentage of correct responses. The difference between RT in congruent and incongruent trials was defined as Dif-RT and the difference between the percentage of correct responses in congruent and incongruent was defined as Dif-error. These variables measure the inhibitory control of attention by participants.

The Kolmogorov–Smirnov tests and also investigation of kurtosis and skewness of different variables revealed that all data were normally distributed. Analyses results were carried out in SPSS using the ANOVA test to compare sleep quality scores between different groups, and a MANOVA to compare PVT and Flanker scores between different groups. A Tukey's test, an independent sample T-test, and a Spearman's correlation test were used for specific comparisons. The significance level for each test was $p = 0.05$.

RESULTS

Number, mean age, mean seafaring experience, and ranges are presented in Table 1. In order to analyse the results, the participants were divided into four groups from the deck officers' rank perspective and into three groups from the duration at sea perspective (0–30 days, 31–60 days, 61–90 days).

Table 1. Number, age mean, seafaring experience mean and seafaring experience ranges of deck officers

	Master	Chief Officer	2nd Officer	3rd Officer
Number	22	17	16	15
Age mean	48.9 ± 5.57	40.41 ± 3.31	33.56 ± 2.22	29.93 ± 1.70
Seafaring experience mean [year]	14.45 ± 1.26	8.41 ± 1.27	5.31 ± 0.94	3.33 ± 0.81
Seafaring experience ranges [year]	12–16	7–11	4–7	2–5

Table 2. Represents officers' performance on the Psychomotor Vigilance Task (PVT) and Flanker task according to deck officers' rank and duration at sea

	Deck Officers' rank			
	Master	**Chief Officer**	**2nd Officer**	**3rd Officer**
Number	22	17	16	15
RT [ms]	357.28 ± 19.10	351.64 ± 14.51	346.67 ± 25.67	330.22 ± 18.12
Lapse	1.81 ± 0.66	2.39 ± 0.71	2.41 ± 0.38	1.83 ± 0.64
Dif-RT	45.26 ± 8.99	51.94 ± 15.78	53.30 ± 18.29	61.64 ± 27.99
Dif-error	0.24 ± 0.15	0.36 ± 0.20	0.46 ± 0.27	0.40 ± 0.26
	Duration at sea			
	First (0–30 days)	**Second (31–60 days)**	**Third (61–90 days)**	
Number	21	28	21	
RT [ms]	355.73 ± 26.13	339.39 ± 18.62	350.54 ± 17.23	
Lapse	2.30 ± 0.48	1.86 ± 0.74	2.19±0.67	
Dif-RT	53.73 ± 15.01	47.91 ± 21.14	56.31 ± 18.24	
Dif-error	0.45 ± 0.26	0.27 ± 0.17	0.37 ± 0.24	

RT — reaction time

ANALYSIS OF THE COGNITIVE PERFORMANCE (PVT AND ARROW FLANKER TASKS)

The values of different components of the PVT and Arrow Flanker according to two independent variables, namely deck officers' rank and duration at sea is shown in Table 2.

A MANOVA test was conducted to study the effects of duration at sea and deck officers' rank separately on different components of the deck officers' PVT performance. The overall effect of the interaction between duration at sea and rank was not significant. The results of MANOVA test showed that the respondents' performance in the PVT task significantly varied by their rank ($F_{(6,130)} = 5.447$, $p < 0.001$), Wilk's $\Lambda = 0.639$, partial $\eta^2 = 0.201$. In particular, it significantly affected the reaction time and the number of lapses. A Tukey's test with respect to RT revealed a significant difference between masters and third officers ($p = 0.001$), between chief officers and third officers ($p = 0.016$). Also, the difference between first officers and masters ($p = 0.026$), between the second officers and masters ($p = 0.023$) was significant with respect to the number of lapses. The results of MANOVA test showed that the respondents' performance in the PVT test varied by duration at sea significantly ($F_{(4,132)} = 4.167$, $p = 0.003$), Wilk's $\Lambda = 0.788$, partial $\eta^2 = 0.112$. In particular, its effect on the number of lapses and on the reaction time were significant. A Tukey's test revealed a significant difference in reaction between the officers in the first range and the second range ($p = 0.025$). Also, it revealed a significant difference in the number of lapses between the first range and second range ($p = 0.025$) and between third range and second range ($p = 0.038$).

The average response time in all of the trials of the Flanker task was 454.92 ± 18.37 ms, in congruent trials it was 428.89 ± 22.80 ms and in incongruent trials it was 480.96 ± 19.40 ms, showing that participants had slower response time in incongruent trials. The percentage of correct answer in all of the trials was 99.41 ± 0.27, with 99.58% ± 0.25 in congruent trials and 99.26% ± 0.34 in incongruent trials, showing that participants had slightly lower accuracy in incongruent trials. The MANOVA test was conducted to study the effects of the different groups of duration at sea and deck officers' rank on different components of the deck officers' Arrow Flanker performance. The results of MANOVA test showed that the respondents'

Table 3. Sleepiness comparison between the day shifts and night shifts for each group of the officers and the comparison between the sleepiness processes during each shift

	Deck Officers' rank				
	Master	**Chief Officer**	**2nd Officer**	**3rd Officer**	**P-value**
KSS1	4.54 ± 0.85	5.17 ± 0.88	5.18 ± 0.91	4.20 ± 0.86	0.003
KSS2	4.81 ± 1.18	5.35 ± 0.70	5.43 ± 1.03	4.60 ± 0.73	0.038
KSS3	5.22 ± 1.15	5.88 ± 0.85	5.56 ± 1.20	5 ± 1.25	0.130
	Duration at sea				
	First range	**Second range**	**Third range**	**P-value**	
KSS1	5.23 ± 0.94	4.35 ± 0.91	4.85 ± 0.79	0.004	
KSS2	5.52 ± 1.07	4.71 ± 0.93	5 ± 0.83	0.017	
KSS3	5.66 ± 1.27	5.25 ± 1.10	5.38 ± 1.07	0.455	

KSS — Karolinska Sleepiness Scale

Table 4. Sleep quality according to the different ranges of duration at sea. The worst sleep quality was observed respectively in the officers who are in the first range (i.e., respondents who spent between 0 to 30 days) and the third range (i.e., respondents who spent between 61 to 90 days)

	Deck Officers' rank				
	Master	**Chief Officer**	**2nd Officer**	**3rd Officer**	**P-value**
PSQI	6.63 ± 0.90	7.23 ± 1.14	7.31 ± 1.35	6.13 ± 1.30	0.018
	Duration at sea				
	First range	**Second range**	**Third range**	**P-value**	
PSQI	7.28 ± 1.30	6.28 ± 0.97	7.09 ± 1.22	0.007	

PSQI — Pittsburgh Sleep Quality Index

performance in this task significantly varied by their rank ($F_{(6,130)}$ = 2.624, p = 0.020), Wilk's Λ = 0.796, partial η^2 = 0.108. In particular, rank significantly affected Dif-error. A Tukey's test with respect to Dif-error revealed significant difference between second officers and masters (p = 0.018). The results of MANOVA test, showed that the respondents' performance in the Arrow Flanker task significantly varied with duration at sea ($F_{(4,132)}$ = 3.424, p = 0.011), Wilk's Λ = 0.821, partial η^2 = 0.094. In particular, its effect on the number of Dif-error was significant. A Tukey's test revealed a significant difference in Dif-error between the officers in the first range and the second range (p = 0.024).

KSS ANALYSIS

The average of KSS1, KSS2, and KSS3 values for different ranks among the officers, and the different ranges of duration at sea, are presented in Table 3. The one-way between subject ANOVA results showed that the KSS1 and KSS2 were significantly different for the different ranks of deck officers. The post-hoc Tukey test also demonstrated that the KSS1 scores were significantly higher among the first and second officers, compared to the third officers (p = 0.014, p = 0.013, respectively). Moreover, the one-way between subject ANOVA results also showed that KSS1, and KSS2 were significantly different for the different ranges of duration at sea. Additionally, the post-hoc Tukey test also revealed that the KSS1 scores were significantly higher among the officers present in the first range, than the officers in the second range (p = 0.03). Furthermore, the results of this test for the KSS2 scores, show that the officers in the first range have significantly higher scores compared to the officers in the second range (p = 0.012).

PSQI ANALYSIS

The mean sleep quality score of the participants over the last month was 6.82 ± 1.22 and this indicated that their mean scores were significantly higher than standard score which is 5 (p < 0.001) that represents poor sleep quality. According to the results, 89% of the respondents had low sleep quality. The mean sleep quality for the different deck officers' rank is presented Table 4. In the following data analysis, a one-way ANOVA was carried out to study the difference between the mean sleep quality scores of different groups of deck officers' rank, revealing a significant difference between the sleep quality of the deck officers. A Tukey's test revealed a significant difference between the first officer and third officers (p = 0.045) and also between the second officers and third officers (p = 0.031).

Table 5. Represents Pearson correlation test. The results show that sleep quality affects their Psychomotor Vigilance Task (PVT) performance as indexed by reaction time (RT) and lapse and also sleepiness of participants

Variables	Correlation	P-value
PVT		
RT-pre	0.386**	0.001
RT-post	0.361*	0.002
Lapse-pre	0.223	0.064
Lapse-post	0.215	0.074
Arrow Flanker		
Dif-RT(pre)	0.027	0.824
Dif-RT(post)	0.094	0.437
Dif-error(pre)	0.329*	0.005
Dif-error(post)	0.505**	0.000
Karolinska Sleepiness Scale (KSS)		
KSS1	0.365*	0.002
KSS2	0.332*	0.005
KSS3	0.385**	0.001

*p < 0.05; **p < 0.001

A one-way ANOVA was also carried out to study the difference between the mean sleep quality scores of different groups of duration at sea, revealing a significant difference between the sleep quality of the deck officers. A Tukey's test revealed that the officers in the first range had significantly lower sleep quality than the officers in the second range (p = 0.011) and also that the officers in the third range had significantly lower sleep quality than the officers in the second range (p = 0.046).

Results of the Pearson's correlation in Table 5 showed a positive and significant correlation between sleep quality of officers during tour of duty and their cognitive performance and sleepiness during cargo handling operation.

DISSCUSION AND CONCLUSIONS

The fatigue and sleepiness caused by poor sleep quality, high workload and long working hours are the most critical factors that impair the performance of navigation officers during cargo handling operations. The comparison of the participants' performance on the PVT and their KSS ratings in the present study with similar research conducted in simulator like HORIZON shows more fatigue in the real situation. The results of the present study show that the officers with 4–8 shifts have more fatigue than the officers with 6–6 shifts in simulator-based studies like HORIZON [28].

The analysis of the results of the PVT, Flanker tasks, KSS and also PSQI based on deck officer's rank revealed that second officers and first officers had the highest sleepiness and weakest sleep quality and cognitive performance with regards most variables, and subsequently they experienced more fatigue.

During the tour of duty, the first and second officers have workshifts from 4am to 8am and 24 to 4 am, respectively. Performing the workshifts against the circadian rhythm and in times when the highest pressure for sleeping suppress the human body, results in the weakening of the cognitive performance and acute fatigue in the short term, and in chronic fatigue and sleep deprivation in the long term [9, 10, 23, 34]. Moreover, sleeping during the day weakens the sleep quality of these officers to a great extent, and would not be sufficiently restorative, which is another reason for their fatigue [16, 48]. When combined with long working hours and the heavy workload of the ABC operations, these problems could be one of the main factors in impairing their performance during sensitive operations such as cargo handling.

Interestingly, although ship masters are usually day workers, their sleep quality is low presumably due to the significant work stress, excessive workload, and need for emergency preparedness [19, 49]. Captains suffer from a disturbed working and rest regime (unfixed working hours, even during the rest waiting for a call to taking place). Numerous captains, for instance, stated that sometimes they have to wake up several times during the night and be present on the bridge after receiving a call from an officer on the bridge to handle the situation [49]. The results of the current study agree with previous results regarding the worse performance of captains in the cognitive tests [50]. Factors such as the variety of inspections at port, time constraints, and receiving numerous e-mails from the shipping company, cargo owners, and ship charterers impose an additional workload on captains [27]. Captains have the greatest seafaring experience and highest age among the deck officers, and increasing age reduces sleep quality and affects fatigue [17, 51]. Also, with an increase in seafaring experience and the increased responsibilities carried out by the officers on ships, their occupational stress and fatigue rises [13]. However, Hystad and Ed [13] stated that older and more experienced mariners are more capable of dealing with the circumstances. Further research is required to give a better understanding of the effect of age and working experience on cognitive performance.

The results obtained regarding duration at sea and sleep quality of the participants also suggest that the participants in the first range, i.e. 0–30 days, had the lowest sleep quality. This finding is in line with previous studies [7, 15], which reflected the difficulty and complexity of the process of adaptation of mariners to different and unique ship conditions on the first days of joining a ship and also some problems like jet lag. Surprisingly, it is stated that two-third of mariners directly start their work shifts without taking rest at the end of a flight after reaching the port where the ship is moored [52] which can cause more problems for night shift workers. It is worth noting that the alteration of the circadian rhythm, the stress of being separated from their families and changes in their sleeping environment not only lead to sleep deprivation but also causes problems such as insomnia, dysthymia and depression [53]. Now, imagine officers who are night shift workers, have joined the ship recently, and have to perform their duty on ABC operations. What a dangerous combination of risk factors this is for them! According to the PSQI, sleep disorders such as feeling warm or cold, coughing, snoring, having nightmares, waking up at midnight, and using sleeping pills were more prevalent among officers, who worked for 0 to 30 days on ships. Although individuals adapt more to the conditions of a tour of duty over the time, the other stressful factors and fatigue resulting from living and working at sea, including sleep debt, chronic sleep loss, and psychological problems resulting from living in the isolated and confined environment increase [51]. This could be the reason for poor sleep quality of officers in the third range (61 to 90 days).

The analysis of the participants' performance in the KSS, PVT and Flanker based on duration at sea suggest that the participants in the first range, i.e., 0 to 30 days, who suffered lower sleep quality, showed more sleepiness, higher reaction time and number lapses and also had poorer inhibitory control of attention than the other ranges. These findings are in accordance with the results reported about the increased fatigue and subsequently decrements in sustained attention due to reduced quality and duration of sleep [51, 54]. However, participants who spent 61 to 90 days at sea showed more sleepiness and weaker sleep quality and cognitive performance than the participants in the second range. Chronic exposure to stressors and fatiguing factors, and also the clear relationship between fatigue severity and duration of exposure to fatigue, means that duration at sea negatively affects their cognitive performance, sleepiness and sleep quality. This finding is similar to the findings reported regarding supply vessels [13].

The results of the Flanker task indicate significant differences between some variables and the officers who worked the night shift in the latest tour of duty and stayed between 0 and 30 days or 61 to 90 days on the ship, had poorer inhibitory control of attention and made more mistakes in the Flanker task. These findings are in accordance with the results listed in studies [55] suggesting that individuals working the night shifts committed more errors than day workers. In addition to fatigue and sleep quality, depression is another factor that affects the executive functions of the respondents [56]. However, given the mild to severe depression of mariners [14], it could be stated that depression affects their response inhibition ability, which calls for further research.

The sleepiness resulting from low sleep quality combined with acute fatigue caused by stressful operations in the port, approaching, and coastal areas can create task deviation and heighten the risk of operational errors by navigation officers by reducing their cognitive abilities [57]. Despite the presence of work and rest hours regulations stipulated in the Maritime Labour Convention (MLC2006) as well as Standards of Training, Certification, and Watchkeeping (STCW), it seems that for commercial reasons, deck officers have to sometimes ignore these regulations [27]. Therefore, it is highly recommended that a new and specific framework is developed, involving a short rest break or nap for deck officers, especially those that joined the ship recently, and have a night shift in the last tour of duty and also have excessive workload in their duties after cargo handling operations. Azimi Yancheshmeh et al. [27, 34] also show that the existence of rest time between the berthing and cargo handling operations can have a significant effect on reducing the sleepiness and improving the cognitive performance of these officers during their first workshift in cargo handling operation.

Recently, the Oil Companies International Marine Forum (OCIMF) and the International Association of Independent Tanker Owners (INTERTANKO) released an article about the necessity of behavioural competency assessment. They believe that in order to reduce incidents, marine industries' primary focus should be placed on training and assessing non-technical skills (soft skills) like team working, communication, situation awareness, decision making, result focus, and leadership which have been named competency domains. It is highly recommended by them to perform these assessments during critical ship operations like ABC [58]. It is worth noting that all of these competency domains are affected by fatigue directly and indirectly, especially during ABC. For example, fatigue can degrade situation awareness or decision making abilities through cognitive performance degradation. Sometimes, seafarers technically know how to perform their duties and also desire to act in that way but have made errors during performance of a task due to fatigue. On the one hand, OCIMF and INTERTANKO suggest that officers with greater experience and higher rank should have more soft skills due to the nature of their responsibilities. However, the present study showed that this group of officers had lower sleep quality and became more fatigued. Hence, it is deemed necessary for the assessor to focus on the level of seafarer fatigue while performing behavioural assessments in order to achieve more precise results.

Moreover, it seems there is a lack of a device similar to alcohol test devices to immediately measure the level of sleepiness in highly regulated industries. Such a device would enable the masters or port state control inspectors to assess the capacity of the deck officers for the accomplishment of their tasks in their work shifts. Furthermore, it should be noted that much research demonstrates that insomnia is one of the main consequences of chronic sleep restriction and chronic sleep debt which is prevalent among seafarers [19, 59]. Using sleeping pills can be useful but this method has side effects like headache, dizziness, memory problems, and sleepiness. Non-pharmacological solutions such as a relaxation technique are one of the best methods for resolving sleep problems.

It is worth mentioning that cost-effectiveness is still one of the priorities for ship and cargo owners and maritime transportations companies due to the culture dominating maritime transportation. For example, deck officers may arrive at a destination with fatigue and poor sleep quality due to long tour of duty and then be involved in the tiresome and complicated approaching and berthing operations. Before handling cargo operations, such individuals need a reasonable amount of time to recover from work-related fatigue. However, the stakeholders, shipping companies, and cargo owners are not interested in the increased duration of stay of vessels in wharves due to the dire financial consequences or add a cargo officer to help the officers during cargo handling operation. This priority may increase the likelihood of a commitment to errors by the navigation officers.

LIMITATIONS OF THE STUDY

Ship's type, cargo, and the crew nationality all contribute to the degree of fatigue experienced by the ship crew [19]. However, in the present study, only ocean-going vessels were studied. Another limitation of the present study was its cross-sectional structure. Hence, any decisive conclusion needs to be drawn from further longitudinal research [60]. The seafarers were also assured that their participation in this study was not going to have any adverse occupational effect on them. Unfortunately, in the marine community, the inappropriate culture and fear of dismissal by the shipowners or shipping companies causes problems. Hence, workers tried to hide many of their problems and hardships while answering the surveys [31]. In addition to the above-mentioned issues, there are other limitations associated with this field study such as time restrictions on presence on board. Similarly, the authors had to use subjective sleep quality which in comparison of objective sleep quality has lower precision.

It should be noted that in order to evaluate the sleep quality among those individuals who had worked offshore for less than a month, they were asked to answer questions proportionate to the length of time they were at sea.

Another limitation of this study is the low number of participants. Finally, it should be noted that the most important information about fatigue comes from on-board field studies. While time-consuming and personnel intensive, it is these studies that best allow a realistic assessment of the working and living conditions likely to produce high levels of fatigue and which therefore are needed in greater numbers.

DATA AVAILABILITY

The datasets generated during and/or analysed during the current study are available from the corresponding authors on reasonable request.

CONFLICT OF INTEREST

The authors declare no competing interests.

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