Fatigue in the ferry industry and its relation to roster patterns, schedules, and job roles

Downloaded from: https://research.chalmers.se, 2026-03-19 04:30 UTC

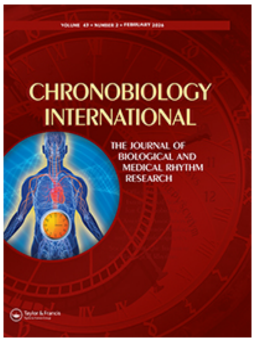
Citation for the original published paper (version of record):

Sjörs, A., Ahlström, C., Jones, W. et al (2026). Fatigue in the ferry industry and its relation to roster patterns, schedules, and job roles. Chronobiology International, 43(2): 289-304.
http://dx.doi.org/10.1080/07420528.2025.2599353

N.B. When citing this work, cite the original published paper.

research.chalmers.se offers the possibility of retrieving research publications produced at Chalmers University of Technology. It covers all kind of research output: articles, dissertations, conference papers, reports etc. since 2004. research.chalmers.se is administrated and maintained by Chalmers Library

(article starts on next page)



Taylor & Francis
Taylor & Francis Group

Chronobiology International
The Journal of Biological and Medical Rhythm Research

ISSN: 0742-0528 (Print) 1525-6073 (Online) Journal homepage: www.tandfonline.com/journals/icbi20

Fatigue in the ferry industry and its relation to roster patterns, schedules, and job roles

Anna Sjörs Dahlman, Christer Ahlström, Wendy Jones, Sally Maynard, Adam Asmal & Ashleigh Filtness

To cite this article: Anna Sjörs Dahlman, Christer Ahlström, Wendy Jones, Sally Maynard, Adam Asmal & Ashleigh Filtness (2026) Fatigue in the ferry industry and its relation to roster patterns, schedules, and job roles, Chronobiology International, 43:2, 289-304, DOI: 10.1080/07420528.2025.2599353

To link to this article: https://doi.org/10.1080/07420528.2025.2599353

© 2025 The Author(s). Published with license by Taylor & Francis Group, LLC.

Published online: 15 Dec 2025.

Submit your article to this journal

Article views: 420

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=icbi20

CHRONOBIOLOGY INTERNATIONAL
2026, VOL. 43, NO. 2, 289–304
https://doi.org/10.1080/07420528.2025.2599353

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

OPEN ACCESS Check for updates

Fatigue in the ferry industry and its relation to roster patterns, schedules, and job roles

Anna Sjörs Dahlman[a,b], Christer Ahlström[a,c], Wendy Jones[d], Sally Maynard[d], Adam Asmal[d], and Ashleigh Filtness[d]

[a]Department of Traffic and Road Users, Swedish National Road and Transport Research Institute, Linköping, Sweden; [b]Department of Electrical Engineering and SAFER, Chalmers University of Technology, Gothenburg, Sweden; [c]Department of Biomedical Engineering, Linköping University, Linköping, Sweden; [d]Transport Safety Research Centre, Loughborough University, Loughborough, UK

ABSTRACT
Fatigue is a known contributor to maritime accidents, with roster patterns, shift schedules, and job roles identified as key risk factors in long-distance shipping. This exploratory study investigates whether similar patterns exist in ferry operations. Sixty-three UK ferry workers participated in a field study involving at least 2 weeks of on-duty data collection. Participants wore activity monitors and completed sleep diaries and 9-point scale ratings of sleepiness (KSS), stress, and workload. The sample included four roster types, three work schedules, and six job roles; 52% slept onboard, while others returned home between shifts. Sleepiness on duty (KSS ≥ 7) was reported in 27% of shifts. The shortest sleep was observed in participants working 12-h split shifts and 8 weeks on/4 weeks off rosters. However, the greatest number of shifts with KSS ≥ 7 were found in workers on 2 weeks on/2 weeks off and 1 week on/1 week off rosters. Bridge crew reported the most stress, and service crew the highest workload. Sleep location (onboard vs. home) did not significantly affect outcomes. Fatigue was widespread across roles and schedules, suggesting that mitigation strategies should target the entire workforce. Split shifts should be avoided, and current regulations are insufficient to manage fatigue effectively.

ARTICLE HISTORY
Received 12 June 2025
Revised 7 October 2025
Accepted 28 November 2025

KEYWORDS
Fatigue; maritime; seafarers; sleepiness; work schedules; shiftwork

Introduction

Fatigue is a recognised risk factor for incidents in seafaring, much like in other transport sectors such as rail and aviation. Several maritime studies have concluded that fatigue is prevalent among seafarers, correlating with a higher risk of accidents and negative impacts on both mental and physical health (Jepsen et al. 2015; Grech 2016; Nittari et al. 2024). This fatigue has been a contributing factor in many serious incidents and collisions within the maritime industry (Shattuck et al. 2023). Investigations into these occurrences have pinpointed common triggers of fatigue, such as extended working hours, shift work, lack of sufficient sleep, and night-time operations. These factors can lead to cognitive impairment, poor judgement, and communication breakdowns among crew members. In some cases, the investigation showed that multiple crew members were affected simultaneously, thereby exacerbating operational challenges.

Although there are various definitions of fatigue, it can be characterised by features such as subjective sleepiness, changes in psychological state, reduced ability to perform a task efficiently, reduced alertness, and difficulty maintaining focus on a task or activity for an extended period (Kerkamm et al. 2022; Rüpke and Athanassiou 2024). Here, fatigue is considered to be a psychological and/or physical impairment which has the potential to reduce optimal performance. It is multifaceted, encompassing pressures from both endemic sleepiness relating to the body's homeostatic and circadian pressures, and task-related fatigue. Sleepiness refers to the physiological drive to fall asleep due to insufficient sleep or time of day. Thus, sleepiness is a contributing factor to fatigue, often referred to as sleep-related fatigue (May and Baldwin 2009).

Work schedules and roster patterns significantly influence seafarer fatigue, both in terms of sleep-related and task-related fatigue. For example, there is a clear difference in fatigue risk between daytime and nighttime workers, as well as between different shift schedules (Jepsen et al. 2015). Common maritime shift schedules include 4 h on duty followed by 8 h off, and 6 h on duty followed by 6 h off. The 6 on/6 off schedule is consistently associated with higher levels of on-duty sleepiness compared to the 4 on/8 off schedule (Härmä et al. 2008; Lützhöft et al. 2010; Short et al. 2015), presumably due to longer working hours per day and

CONTACT Anna Sjörs Dahlman anna.dahlman@vti.se The Swedish National Road and Transport Research Institute (VTI), Box 8072, Göteborg 402 78, Sweden

© 2025 The Author(s). Published with license by Taylor & Francis Group, LLC.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

no possibility for a longer sleep period at night (Jepsen et al. 2015; Mansyur et al. 2021).

Most previous research has focused on shipping, tanker, fishing, or naval vessels, with a notable lack of studies on ferry operations (Behavioural Insights Team, Transport Research Laboratory 2023). In ferry operations, Gander (2005) found that 61% of officers on New Zealand inter-island ferries reported being often or always affected by fatigue while on duty. Furthermore, 26% of the sample recalled being involved in a fatigue-related incident or accident in the previous 6 months. Sparks (1992) reported that among masters, mates, and pilots in a State Ferries system, 19% had experienced near misses where fatigue was a significant factor, 43% had fallen asleep at work, and 23% had done so more than once per month. In another survey of ferry operators, 18% of respondents stated they had fallen asleep at work at least once in the previous 12 months, while 59% indicated that they had to fight sleepiness at work at least once a month (Filtness et al. 2024).

There is also a lack of studies on the impact of different week-by-week roster patterns in ferry operations (Behavioural Insights Team and Transport Research Laboratory 2023). It is notable that shift patterns commonly used across the maritime industry, such as 4 on/8 off or 6 on/6 off, are not common in ferry operations. The present study was conducted within UK waters, where a variety of shift and roster patterns are employed by ferry operators to meet route demands. Most seafarers work 12 h per day, but the distribution of work hours varies according to job role. The route length and intensity determine the shift schedules and roster patterns used by operators (Behavioural Insights Team and Transport Research Laboratory 2023).

Seafarers typically live onboard the vessel, away from family and friends for extended periods; however, in ferry operations, some operators expect their crew to travel home daily after their shifts, similar to non-maritime workplaces. As a result, ferries on shorter routes often lack onboard cabins for the crew. Other ferry operators require seafarers to sleep onboard, typically for 2 weeks followed by 2 weeks off, or 1 week on and 1 week off. There is a wide range of patterns, with some involving much longer periods onboard, similar to other maritime sectors.

Overall, the influence of various work tasks, working conditions, and work environments remains under-researched in ferry operations (Dohrmann and Leppin 2017). However, Dohrmann et al. (2020) found that higher work demands and lower job control were associated with increased sleepiness and reduced energy levels among Danish ferry employees. Given that ferry shipping is characterised by tight timetables and high pressure to ensure the safe and timely delivery of passengers around the clock (Oldenburg et al. 2009), it is surprising that there are so few studies on workload and stress in ferry crews.

The purpose of this study was to explore the relationship between shift/roster patterns and fatigue, sleepiness, and workload among seafarers in ferry operations. It also aimed to assess the potential consequences of fatigue for different job roles and identify the key factors that cause and exacerbate fatigue. The study focused on the prevalence of fatigue during normal operations, which was assessed through measurements of the amount of sleep seafarers have before starting their shifts, and the level of subjective sleepiness, stress, and workload experienced while on duty.

Materials and Methods

The data were collected onboard vessels during normal operation on specific ferry routes and at home between work shifts. The study was exploratory and had a mixed design, allowing for comparisons between participants with different roles, schedules, and rosters. Participants maintained a sleep/wake diary and wore a sleep and activity tracker for approximately 4 weeks, documenting sleep quantity, quality, and timing. Recordings continued throughout the 4-week period, including both rest and workdays. Work schedules were documented for all participants. One item, nine-point Likert scales were used to record subjective sleepiness, stress and workload levels every day. Subjective sleepiness was rated using the Karolinska Sleepiness Scale (KSS, Åkerstedt and Gillberg 1990) and matching 9-point ratings scales for stress and workload were also completed. KSS ranged from 1 = extremely alert to 9 = very sleepy, great effort to keep awake. Participants were given verbal and written information about the labels for each step of the KSS. The stress and workload scales did not have labelled steps. Scores ≥7 were taken to indicate high sleepiness, stress and workload.

Participants

Sixty-three participants were enrolled in the study; they were recruited onboard a total of seven vessels operated by three different ferry companies. The participants, who had various job roles and work schedules, worked on routes sailing in and out of UK ports. Each participant received an incentive of £100 upon completing the full data collection. The onboard data collection took place in February, March and April 2024 and was adapted to the participants' work schedules so that the individual participants' 4-week data collection window included at least 2 weeks of data collection while on duty. Inclusion criteria required participants to have worked as seafarers regularly for at least 2 y, to be in good health (self-reported), and not to have been on sick leave for more than 3 d in the previous 2 months. Participants also agreed to use a wearable sleep and activity tracker 24 h a day for 4 weeks and to complete questionnaires and sleep/wake diaries.

The study was conducted in accordance with the declaration of Helsinki, and informed consent was obtained by all participants. The study protocols were approved by the Loughborough University ethics committee.

Procedure

Seafarers received written information about the study procedures and had the opportunity to discuss participation with a researcher before providing informed consent. An entry questionnaire was completed, covering the participant's background as a seafarer, education, sleep and fatigue issues, health, and past sleep-related incidents.

Participants were provided with a wearable device (Charge 6, Fitbit Inc., San Francisco, CA) and a mobile phone web application for sleep diaries to track their sleep/wake history. Before the first day of onboard data collection, participants began wearing the Fitbit device and filling in sleep diaries. The Fitbit, worn around the wrist like a watch, recorded sleep and Fitbit sleep score by tracking movement and heart rate. The Fitbit sleep score is a single metric, on a scale of 0–100, where higher numbers indicate better sleep. Sleep scores are categorized as excellent (90–100), good (80–89), fair (60–79), and poor (less than 60). Participants also completed a reaction time task before and after each work shift using the mobile phone app, but due to technical difficulties, reaction time data are not reported here.

Data was collected for all on-duty and off-duty days during the 4-week period; this included wearing the Fitbit and completing sleep diaries in the morning and at bedtime. In addition, during work shifts, participants regularly reported sleepiness on the KSS scale. They were instructed to report KSS every 2 h if their work tasks allowed, with the value reflecting their average feeling over the previous 5 min. The exact timing for KSS reporting varied between participants depending on their schedules and work tasks. KSS ratings were also recorded immediately after the work shift.

At bedtime, participants answered questions about their current sleepiness and perceived stress and workload during the work shift (all rated on a scale from 1 to 9) and indicated in the sleep diary application whether it was a workday or a day off. Upon waking, they reported sleep quality, time taken to fall asleep, and sleepiness upon waking.

After completing data collection both at home and onboard, participants filled in an exit questionnaire, returned the Fitbit device, and received compensation for their participation.

Data Analysis

Data collected on workdays between 28 February and 10 April 2024 were used for analysis. Job roles were categorized into six groups: Captains/Masters, Bridge crew (officers and mates), Managers not on the bridge (bosuns, chief stewards, chief engineers, and head chefs), Deck crew (ratings and able-bodied seafarers), Service crew (on-board services, stewards, and restaurant employees), and Engine crew (engineers and electricians).

Participants' work schedules were described and categorized based on hours worked per 24 h and whether they worked during the day or night. Three main types of work hours were defined: 12 h on/12 h off, 12-h split shifts, and 6–9 h on/15–18 h off. Typical work hours in the 12-h split shift category were: 6 h on, 4 h off, 6 h on, 8 h off, with some variation in the distribution of work and rest among participants. In the 6–9 h on/15–18 h off category, participants worked one shift per 24 h, with varying start times. Most seafarers in this category had rotating schedules, with shift lengths ranging from 6 to 9 h and alternating between morning and afternoon shifts. Night work was defined as at least 3 h of work between 23:00 and 06:00 and was regularly observed only in participants working a 12 h on/12 h off schedule. Six participants had ship maintenance duties during the first 2 weeks of the study, working a 12 h on/12 h off schedule initially, followed by 6–9-h daytime shifts. These participants, along with two others with irregular schedules, were categorized as Other. The categorization was based on hours worked during the study, though some participants may have worked different schedules prior to the study.

Rosters were categorized based on the number of days worked per week or the number of weeks on and off duty. Four main types of rosters were defined: 1 week on/1 week off, 2 weeks on/2 weeks off, 8 weeks on/4 weeks off, and 5 d of work per week. Participants working 5 d per week either followed a 5 d on/2 d off schedule or a more irregular pattern, totalling 35–37 h of work per week. Six participants had ship maintenance duties during the first 2 weeks of the study, resulting in a different roster than usual. Eight participants had irregular rosters or were the only ones with a particular roster, and these 14 participants were categorized as Other.

Not all participants had complete data for all outcome variables. Actual work hours recorded by the operator were available for 51 participants. Work hours for a further 12 participants were determined based on information provided at onboarding, combined with standard work schedules and diary entries. Sufficient diary entries to analyse self-reported sleepiness were available from 56 participants. Diary entries provided data from 914 working days, with participants completing 4274 KSS ratings. Approximately 28% of the working days lacked sleep diary entries and accompanying KSS, stress, and workload ratings, and 45% lacked bedtime ratings. The high share of missing values was due to participants skipping or ignoring entries, as well as technical issues with the web application when internet connections were weak or unavailable. The web application was designed to store data offline as long as the webpage remained open, but occasional data losses occurred if the webpage had to be reloaded or revisited while offline.

Inspection of the Fitbit data revealed that the motion of the vessel interfered with automatic sleep scoring for some participants sleeping onboard. All Fitbit sleep data were therefore visually inspected, and sleep duration was manually corrected based on movement data from the Fitbits, combined with diary entries of bedtime and wake-up time. Automatic sleep scoring was used in 69% of the sleep duration data entries.

Statistical Analysis

Separate analyses of variance (ANOVAs) were conducted to model each outcome variable as a function of sleep location, job role, schedule type, and roster type. Participants were included as a random nested factor to account for inter-individual variations. The outcome variables analysed were sleep duration, self-rated sleep quality, Fitbit sleep score, KSS, stress, and workload. Only data from workdays were analysed and sleep durations were from the main sleep period before starting the work shift. Effect sizes were estimated as the proportion of total variance explained by the main factor in the ANOVAs (η^2). According to the benchmarks provided by Cohen (1988), $\eta^2 \approx 0.01$ indicates a small effect size, $\eta^2 \approx 0.06$ indicates a medium effect size, and $\eta^2 \geq 0.14$ indicates a large effect size.

Logistic regression analyses were performed to investigate which work factors were associated with reaching KSS ≥ 7 during a work shift and with sleep durations ≤5 h. Separate analyses were conducted with sleep location, job role, schedule type, and roster type as covariates, and KSS threshold (KSS ≥ 7 or KSS < 7) or sleep duration (≤5 h or >5 h) as the dependent variables. Captain/Master was chosen as the reference level for job roles, 5 d per week for schedule types, and 12 h on/12 h off for roster type. Effect sizes were estimated as the proportion of variance in the outcome explained by the fixed effects, excluding contributions from random effects (marginal R^2) (Nakagawa and Schielzeth 2013). The threshold of KSS ≥ 7 was selected because both performance-based and physiological indicators of sleepiness begin to increase exponentially at this level (Åkerstedt et al. 2014). The threshold of ≤5 h for sleep duration was more arbitrary but was based on research indicating that sleep durations of less than 5–6 h per night can lead to cognitive impairment and reduced next-day work performance (Miyata et al. 2013; Li et al. 2022).

Differences between subgroups of participants in background characteristics and work details, derived from the entry questionnaire, were analysed using chi-square tests, one-way ANOVAs, and t-tests, where applicable.

A post hoc power analysis was conducted for the ANOVA models focusing on the main effects of sleep location, job role, schedule type, and roster type. Assuming a medium effect size (Cohen's $f = 0.25$), a significance level of $\alpha = 0.05$, and a total sample size of 63 participants, the estimated statistical power was approximately 0.15. This low power indicates a high risk of Type II errors, meaning that true effects may not be detected. Given the exploratory nature of this study, the findings are intended to generate hypotheses and guide future research rather than provide definitive conclusions.

Statistical analyses were performed using IBM SPSS statistical software version 29.0 and MATLAB 2024A. The alpha criterion was set at 0.05, and Bonferroni correction was applied to compensate for multiple comparisons. Separate analyses were conducted partly due to the limited amount of data per participant, the limited number of participants per work category, and the collinearity and nested relationships between several work factors.

Results

Participant Characteristics

Approximately half of the participants (52%) slept onboard the ship, while 48% went home to sleep

Table 1. Participants' background characteristics from the entry questionnaire.

	Sleep at home		Sleep on board		Total	
	N = 30		*N* = 33		*N* = 63	
Age group (n, %)						
16–24 y	5	17%	2	6%	7	11%
25–34 y	9	30%	14	42%	23	37%
35–49 y	8	27%	12	36%	20	32%
50–64 y	8	27%	5	15%	13	21%
Gender (n, %)						
Female	8	27%	5	15%	13	21%
Male	22	73%	28	85%	50	79%
BMI						
Mean (SD)		28.3 (4.4)		27.0 (4.6)		27.6 (4.5)
Experience as a seafarer (years)						
Mean (SD)		11 (11)		14 (11)		13 (11)
Nationality (n, %)						
British	25	83%	24	73%	49	78%
Other	5	17%	9	27%	14	22%
Education (%)						
No schooling completed	1	3%	0	0%	1	2%
Secondary school degree	4	13%	6	18%	10	16%
Sixth form or college	7	23%	6	18%	13	21%
Bachelor's degree	9	30%	8	24%	17	27%
Master's degree	1	3%	3	9%	4	6%
Trade or technical training	3	10%	6	18%	9	14%
Other	5	17%	3	9%	8	13%
Prefer not to say	0	0%	1	3%	1	2%
Relationship status (n, %)						
Married/Civil partnership	13	43%	14	42%	27	43%
Living with a partner	9	30%	8	24%	17	27%
Separated/Divorced	2	7%	0	0%	2	3%
Single	6	20%	11	33%	17	27%
Children living at home (n, %)						
Yes	12	40%	12	36%	24	38%
No	18	60%	21	64%	39	62%

between work shifts. Details about the participants' backgrounds are presented in Table 1. Most participants (97%) worked full-time, and there were no significant differences in background variables between those sleeping onboard and those sleeping at home.

Five main types of work schedules and rosters were identified among the participants. There were some differences in work schedules and rosters between participants sleeping onboard and those sleeping at home, as shown in Table 2. Statistical tests of these differences were not possible due to a low expected count in several categories. The mean work shift length was 9.0 h (SD 2.9). Twenty-four participants had worked at least one night shift during the data collection period and were included in subgroup analyses of night workers.

General health and sleep over the previous 3 months were rated on a 5-point scale from very good to very bad. Most participants (90%) rated their health as quite good or very good. Six participants (10%) rated their health as neither good nor bad, and none rated their health as quite bad or very bad. Twenty-five participants (40%) rated their sleep as quite good or very good, while 15 participants (24%) rated their sleep as quite bad or very bad. Eleven participants (17%) were smokers, and six (10%) used e-cigarettes. Frequent exercise was reported by 20 participants (32%), occasional exercise by 31 participants (49%), and 12 participants (19%) reported hardly ever exercising. Eight participants (13%) reported never drinking alcohol, while 14 participants (22%) reported drinking alcohol two or more times per week. There were no statistically significant differences in lifestyle or health between seafarers sleeping onboard and those sleeping at home.

In the entry questionnaire, participants reported getting an average of 6.5 h of sleep (SD 1.1) in a 24-h period. This was significantly less than the amount they reported needing to feel rested (7.4 h, SD 1.2) ($t = 5.4$, $p < 0.001$). There were no significant differences in reported actual sleep between different job roles. However, there were significant differences between job roles in the amount of sleep needed to feel rested ($F = 4.7$, $p < 0.001$). Tukey post-hoc tests revealed that Captains reported needing more sleep than Managers not on the bridge ($p = 0.010$) and Engine Crew ($p = 0.036$). Managers not on the bridge reported needing less sleep than Service Crew ($p = 0.010$) and Deck Crew ($p = 0.035$). There were no significant differences in self-reported sleep hours between seafarers sleeping

Table 2. Participants' work details from the entry questionnaire and work schedules.

	Sleep at home		Sleep on board		Total	
	$N = 30$		$N = 33$		$N = 63$	
Employment (n, %)						
Permanently employed by the Operator	27	90%	25	76%	52	83%
Engaged by an agency	0	0%	6	18%	6	10%
Directly employed by the Operator on a fixed term basis (e.g. for a voyage)	3	10%	2	6%	5	8%
Working time (n, %)						
Full time	30	100%	31	94%	61	97%
Part time	0	0%	2	6%	2	3%
Job role (n, %)						
Captain/Master	3	10%	2	6%	5	8%
Managers not on bridge	5	17%	4	12%	9	14%
Bridge crew	3	10%	8	24%	11	18%
Service crew	5	17%	7	21%	12	19%
Engine crew	3	10%	5	15%	8	13%
Deck crew	11	37%	7	21%	18	29%
Watch duties (n, %)						
Yes, on all or most of my shifts	16	53%	13	39%	29	46%
Yes, on some of my shifts	5	17%	10	30%	15	24%
No	9	30%	10	30%	19	30%
Shift schedule (n, %)						
12 h on 12 h off day	7	23%	9	27%	16	25%
12 h on 12 h off day and night	5	17%	11	33%	16	25%
12 h split shift day	0	0%	12	36%	12	19%
6–9 h on 15–18 h off day	12	40%	0	0%	12	19%
Other	6	20%	1	3%	7	11%
Roster (%)						
1 week on 1 week off	4	13%	7	21%	11	18%
2 weeks on 2 weeks off	0	0%	18	55%	18	29%
8 weeks on 4 weeks off	0	0%	7	21%	7	11%
5 d per week	13	43%	0	0%	13	21%
Other	13	43%	1	3%	14	22%

onboard and those sleeping at home, or between different schedules and rosters.

Daytime sleepiness was assessed using the Epworth Sleepiness Scale (ESS, Johns 1991). The mean score was 6.9 (SD 4.2), with 15 seafarers (24%) scoring above the cut-off for excessive daytime sleepiness (ESS > 10). There were no significant differences in ESS scores between job roles, schedules, rosters, or between seafarers sleeping onboard and those sleeping at home.

Sleep Quality and Quantity

The average sleep duration recorded during the field trial for the entire sample of seafarers was 7.1 h (SD 1.5). The distributions of sleep durations per factor are shown in Figure 1. Participants who slept onboard the ship at the end of their shift had a mean sleep duration of 7.0 h (SD 1.5), while those who went home to sleep had a mean sleep duration of 7.2 h (SD 1.5). In addition to the main sleep, 51 naps were recorded across the 914 analyzed workdays. All naps, regardless of whether they were taken at home or at work, were included. The percentage of participants with one or more naps recorded was 4.9% for participants that had their main sleep at home and 6.1% for participants sleeping onboard. Mean nap duration was 2.5 h for participants going home after the shift and 1.9 h for participants sleeping onboard.

ANOVAs of sleep duration in relation to sleep location, job role, schedule type, and roster type revealed statistically significant differences between roster patterns and work schedules (Table 3). Post-hoc tests indicated that participants working 8 weeks on/4 weeks off had significantly shorter sleep durations compared to all other defined roster categories. Conversely, participants working 1 week on/1 week off had significantly longer sleep durations compared to all other roster categories. Regarding schedules, the shortest sleep durations were observed in participants working a 12-h split shift, which were significantly shorter than all other defined work schedules. There were no statistically significant differences in reported sleep quality or in the Fitbit sleep scores between sleep locations, job roles, schedules or rosters (Table 3). Mean self-reported sleep quality was 6.1 (SD 1.8) on a scale from 1 to 9 and mean Fitbit sleep score was 76.3 (SD 8.2) on a scale from 0 to 100. According to Fitbit score categories, sleep quality was poor in 4.0%, fair in 56.8%, good in 37.6%, and excellent in 1.7% of the recorded nights. Figure 1 shows that participants sleeping at home and on board had similar sleep quality scores.

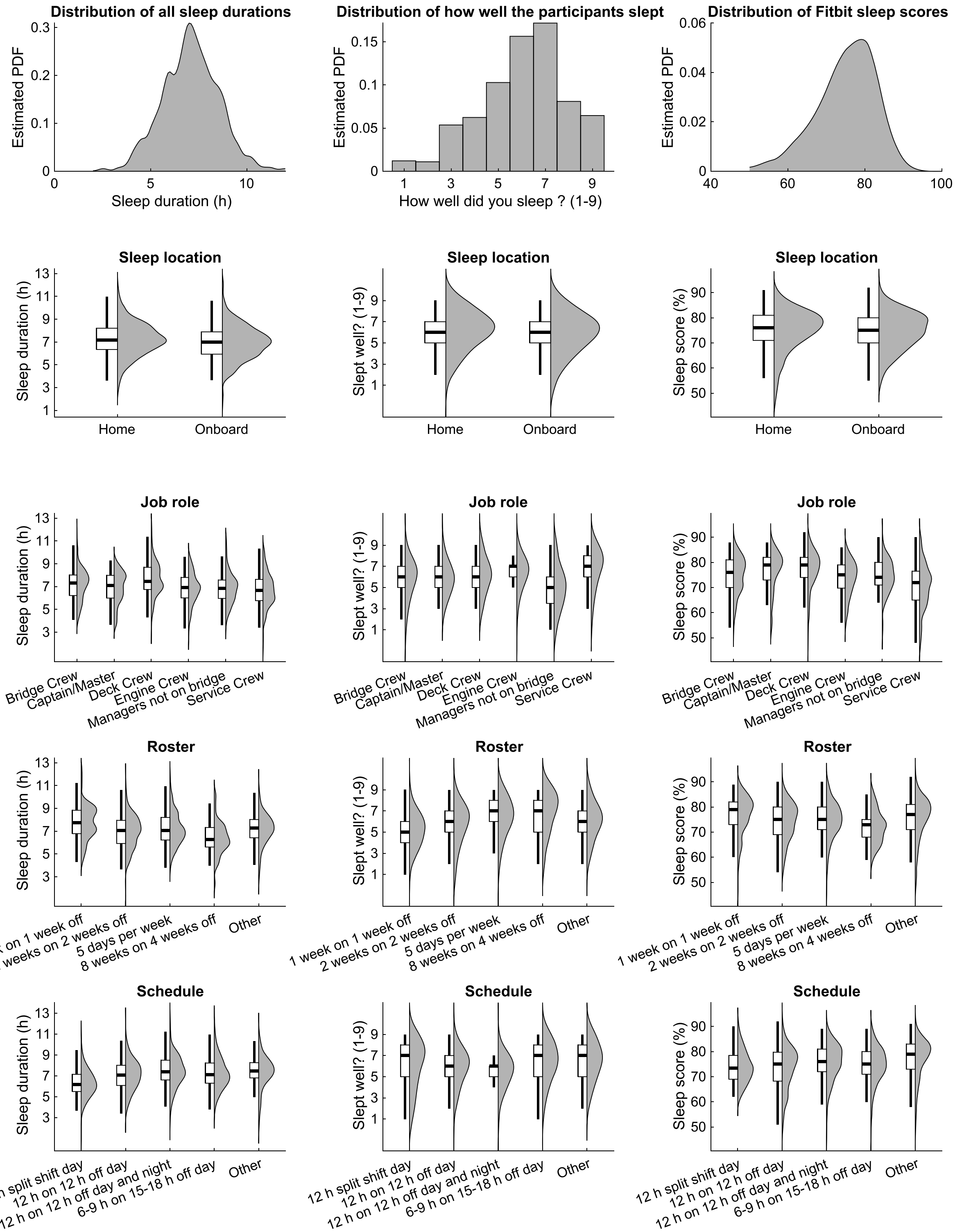


Figure 1. Probability density estimates and box plots of sleep duration (left), self-reported sleep quality (centre) and Fitbit sleep score (right) as a function of the work factors sleep location, working days, job role, schedule type, and roster type, respectively. The top row shows the overall probability density estimates in the full dataset.

The logistic regression analyses of sleep durations ≤5 h did not show any statistically significant associations with any of the work factors (Table 4). Sleep durations ≤5 h were found in 6.6% of all working days, sleep duration ≤6 h were found in 18.0% of all working days, and sleep duration ≤7 h were found in 36.2% of all working days, indicating that most participants did not suffer from severe chronic sleep

Table 3. F and *p* values from separate ANOVAs of various sleep, sleepiness, stress and workload metrics for the four work factors.

	Sleep duration	How well did you sleep?	Fitbit sleep score	KSS_{max}	Stress	Workload
Sleep location	F(1,913) = 1.11 $p = 0.30$ $\eta^2 = 0.007$	F(1,653) = 0.45 $p = 0.51$ $\eta^2 = 0.004$	F(1,634) = 0.0 $p = 0.98$ $\eta^2 = 0.000$	F(1,563) = 5.33 $p = 0.02$ $\eta^2 = 0.051$	F(1,484) = 1.36 $p = 0.25$ $\eta^2 = 0.015$	F(1,484) = 0.01 $p = 0.94$ $\eta^2 = 0.000$
Job role	F(5,913) = 3.03 $p = 0.02$ $\eta^2 = 0.077$	F(5,653) = 3.38 $p = 0.01$ $\eta^2 = 0.012$	F(5,634) = 2.37 $p = 0.05$ $\eta^2 = 0.055$	F(1,563) = 0.21 $p = 0.96$ $\eta^2 = 0.012$	F(1,484) = 4.29 $p = 0.002$* $\eta^2 = 0.181$	F(1,484) = 4.7 $p = 0.001$* $\eta^2 = 0.159$
Roster	F(4,913) = 3.93 $p = 0.007$* $\eta^2 = 0.082$	F(4,653) = 2.98 $p = 0.03$ $\eta^2 = 0.100$	F(4,634) = 0.64 $p = 0.63$ $\eta^2 = 0.015$	F(4,563) = 2.45 $p = 0.05$ $\eta^2 = 0.094$	F(4,484) = 4.54 $p = 0.003$* $\eta^2 = 0.175$	F(1,484) = 8.7 $p \le 0.001$* $\eta^2 = 0.183$
Schedule	F(4,913) = 4.58 $p = 0.003$* $\eta^2 = 0.089$	F(4,653) = 1.45 $p = 0.23$ $\eta^2 = 0.057$	F(4,634) = 1.13 $p = 0.35$ $\eta^2 = 0.028$	F(4,563) = 1.23 $p = 0.31$ $\eta^2 = 0.051$	F(4,484) = 0.64 $p = 0.64$ $\eta^2 = 0.036$	F(1,484) = 1.00 $p = 0.43$ $\eta^2 = 0.037$

η^2 is the proportion of total variance explained. Significant differences are marked with *where the significance level is set to $p \le 0.05$ ($p \le 0.008$ after Bonferroni correction). KSSmax = highest KSS score reported in a work shift.

Table 4. Mixed-effects logistic regression models of sleep durations ≤5 h for the four work factors. B is the estimated coefficient, t is the test statistic, *p* is the *p*-value, N is the number of observations, marginal R^2 is the variance explained by fixed effects, and −2LL is the log likelihood ratio.

	B	t	p	N	-2LL	R^2
Sleep location						
(Intercept)	−3.13	−9.90	<0.001*	914	2561.3	0.18
Sleep location	0.36	0.82	0.41			
Job role						
(Intercept)	−2.30	−2.23	0.02	914	2639.3	0.11
Bridge crew	−0.78	0.65	0.52			
Deck crew	−1.37	−1.24	0.22			
Engine crew	−0.29	−0.25	0.80			
Non-bridge-managers	−0.78	−0.62	0.53			
Service crew	−0.26	−0.24	0.81			
Roster type						
(Intercept)	−3.26	−7.22	<0.001*	914	2618.8	0.29
1 week on 1 week off	−0.82	−0.97	0.33			
2 weeks on 2 weeks off	0.68	1.09	0.28			
8 weeks on 4 weeks off	0.96	1.46	0.15			
Other	0.29	0.46	0.65			
Schedule type						
(Intercept)	−2.95	−6.46	<0.001*	914	2580.6	0.15
12 h on 12 h off day and night	−0.51	−0.77	0.44			
12 h split shift day	0.87	1.34	0.18			
6–9 h on 15–18 h off day	−0.42	−0.62	0.54			
Other	0.20	0.28	0.78			

Significant effects are marked with *where the significance level is set to p ≤ 0.05 (p ≤ 0.01 after Bonferroni correction).

restriction. However, acute sleep loss may still have negative consequences for work performance and safety onboard.

Sleepiness on Duty

In the entry questionnaire, seafarers rated how often they had to fight sleepiness to stay awake while working. One third (33%) of the participants indicated having to fight to stay awake on a monthly basis, while 14% reported having to do so 2–3 times a week or more often. There was no significant difference between seafarers sleeping at home and those sleeping onboard.

The overall mean KSS rating from the diary entries was 4.9 (SD 2.0). KSS scores varied depending on the time of day and the time since the start of the work shift. As shown in Figure 2, KSS patterns differed between groups based on various work factors. In general, ratings were highest (sleepiest) around midnight and lowest in the afternoon, with higher sleepiness ratings for those who slept onboard, and for captains/masters, bridge crew, service crew and managers not on bridge. KSS patterns also differed between rosters. Participants working 8 weeks on/4 weeks off had peaks in the early morning hours and afternoon, while participants in other rosters rated themselves as sleepiest around midnight. When considering work schedule, KSS ratings by participants working 12-h split shifts showed peaks in the afternoon and around midnight, while participants on other schedules only had a peak around midnight. These differing KSS patterns likely reflect differences in rosters and schedules within the study sample.

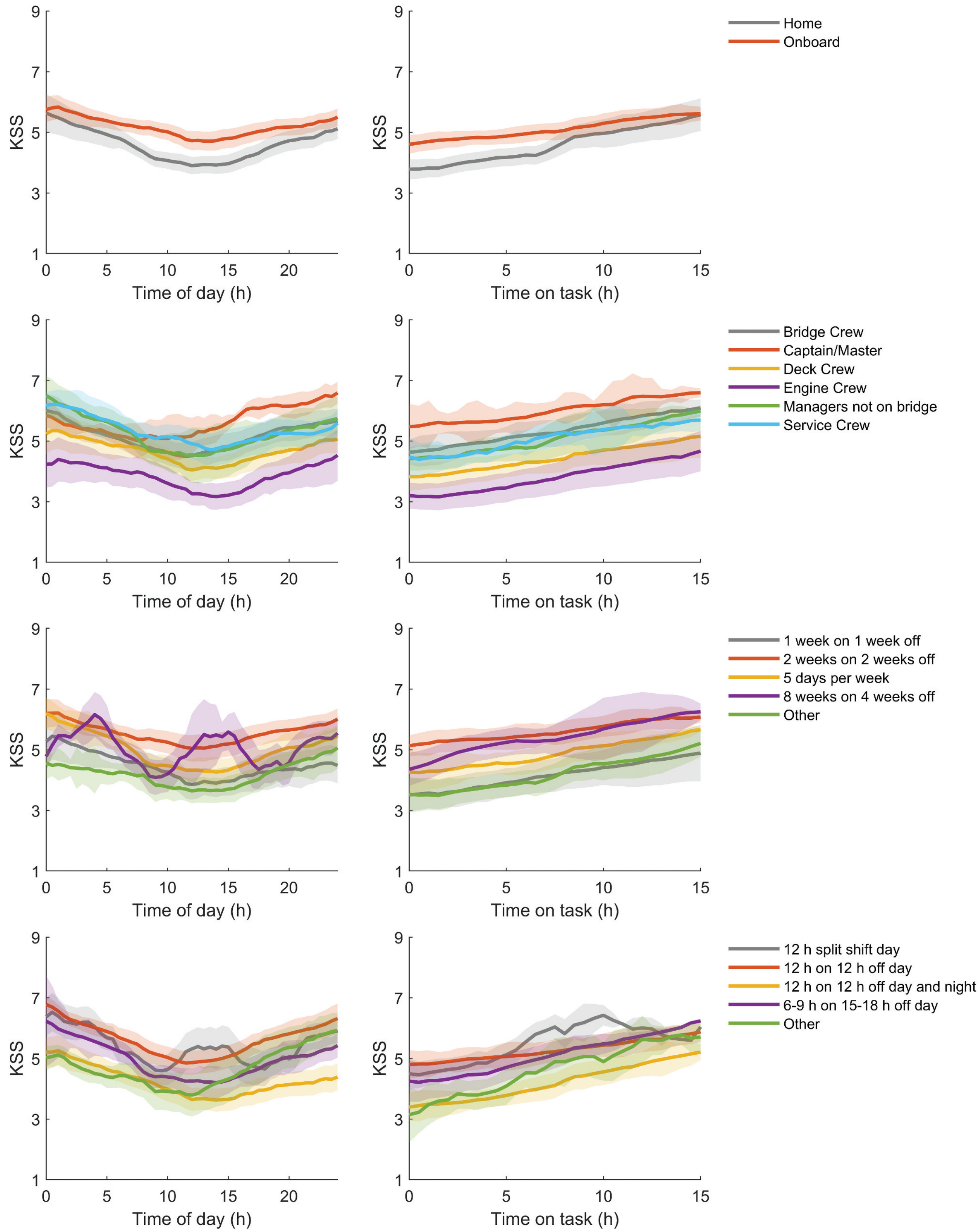


Figure 2. Mean KSS as a function of time of day and time since shift start, split by work factor and groups. The shaded regions represent the standard errors.

All groups showed an increase in sleepiness with increasing hours of work across all work factors. This suggests that task-related fatigue may contribute to the sleepiness ratings. The distribution of the highest KSS score reported in each work shift (KSSmax) across KSS scores (from 1 to 9) is shown in Figure 3. Approximately 24% of all KSS ratings were 7 or higher, and 27% of the work shifts had KSS ≥ 7. Forty-five participants had one or more work shifts with KSS ≥ 7. ANOVA testing of KSSmax for the work factors showed no statistically significant differences between groups (Table 3).

The logistic regression analyses indicated a trend that roster type and work schedule category were related to the risk of having a work shift with KSS ≥ 7 (Table 5). Participants working 2 weeks on/2 weeks off and 1 week on/1 week off had more work shifts with KSS ≥ 7 compared to the other defined roster categories. However, proportion of shifts with high compared to low KSS for those working 1 week on/1 week off was not statistically significantly more frequent after correcting for multiple comparisons. Approximately 38% of the shifts for participants working 2 weeks on/2 weeks off, and 34% of the shifts for participants working 1 week on/1 week off, had KSS ≥ 7. The percentages for the remaining roster types ranged from 14% to 25%. Regarding schedules, the share of work shifts with KSS ≥ 7 was lower for participants working 6–9 h on/15–18 h off (14% with KSS ≥ 7) compared to the other shift categories (20–36%), but this was also not statistically significant after correcting for multiple comparisons. Approximately 17% of the working shifts for participants sleeping at home, and 34% of the working shifts for participants sleeping onboard, had KSS ≥ 7. The difference was not statistically significant.

A comparison between day workers and night workers (participants working at least one night shift during the data collection) showed that there was no general difference between the groups in sleep duration ($F(1,62) = 1.36$, $p = 0.248$) or KSSmax ($F(1,60) = 1.52$, $p = 0.223$). However, comparing night shifts with day shifts within the group of night workers showed that night shifts had significantly shorter sleep durations before the work shift ($F(1,614) = 17.66$, $p < 0.001$, $\eta^2 = 0.028$) and higher mean KSSmax than day shifts ($F(1,158) = 9.76$, $p = 0.002$, $\eta^2 = 0.058$).

Stress

The overall mean rating of stress (possible score from 1 to 9) from the diary entries was 5.2 (SD 5.4). Approximately 4% of all work shifts had stress ≥7. Twenty-four participants had one or more work shifts with stress ≥8. Probability distributions per factor can be found in Figure 3.

ANOVAs of stress scores per work shift in relation to sleep location, job role, schedule type, and roster type revealed statistically significant differences between job roles (Table 3). Post-hoc tests showed that bridge crew provided higher stress ratings than all other categories except non-bridge managers. Non-bridge managers had higher stress levels than deck crew, engine crew, and service crew. There were also significant differences between roster types, with participants working 2 weeks on/2 weeks off reporting higher stress ratings than all other roster types, and participants working 5 d per week providing higher stress ratings than those working 8 weeks on/4 weeks off. Other work factors were not statistically significant.

Workload

The overall mean workload rating was 4.9 (SD 2.0, possible score from 1 to 9). Approximately 22% of all work shifts had a workload rating of 7 or higher. Probability distributions for each factor are shown in Figure 3. ANOVAs of workload per work shift in relation to sleep location, job role, schedule type, and roster type revealed statistically significant differences between job roles and rosters (Table 3). Post-hoc tests indicated that service crew had higher workload ratings than all other job roles, while deck crew had higher ratings than bridge crew. Additionally, participants on the 8 weeks on, 4 weeks off roster had higher workload ratings than those on the 2 weeks on, 2 weeks off, 5 d per week, and other rosters. The 1 week on, 1 week off and 5 d per week rosters had higher ratings than the 2 weeks on, 2 weeks off and other rosters.

Discussion

The main purpose of this study was to explore the relationship between roster patterns, work schedules, job roles and fatigue among seafarers. Key findings indicate significant differences in sleep duration based on schedules and rosters, and significant differences in stress and workload depending on job roles and rosters. Indications are that the 12-h split shift schedule and 8 weeks on/4 weeks off roster were particularly at risk for insufficient sleep, bridge crew experienced most stress, and service crew had the highest workload. The average sleep duration was 7.1 h, and sleep durations ≤5 h were found in 7% of all working days. One-third of participants reported having to fight sleepiness monthly, and 14% reported this 2–3 times a week or

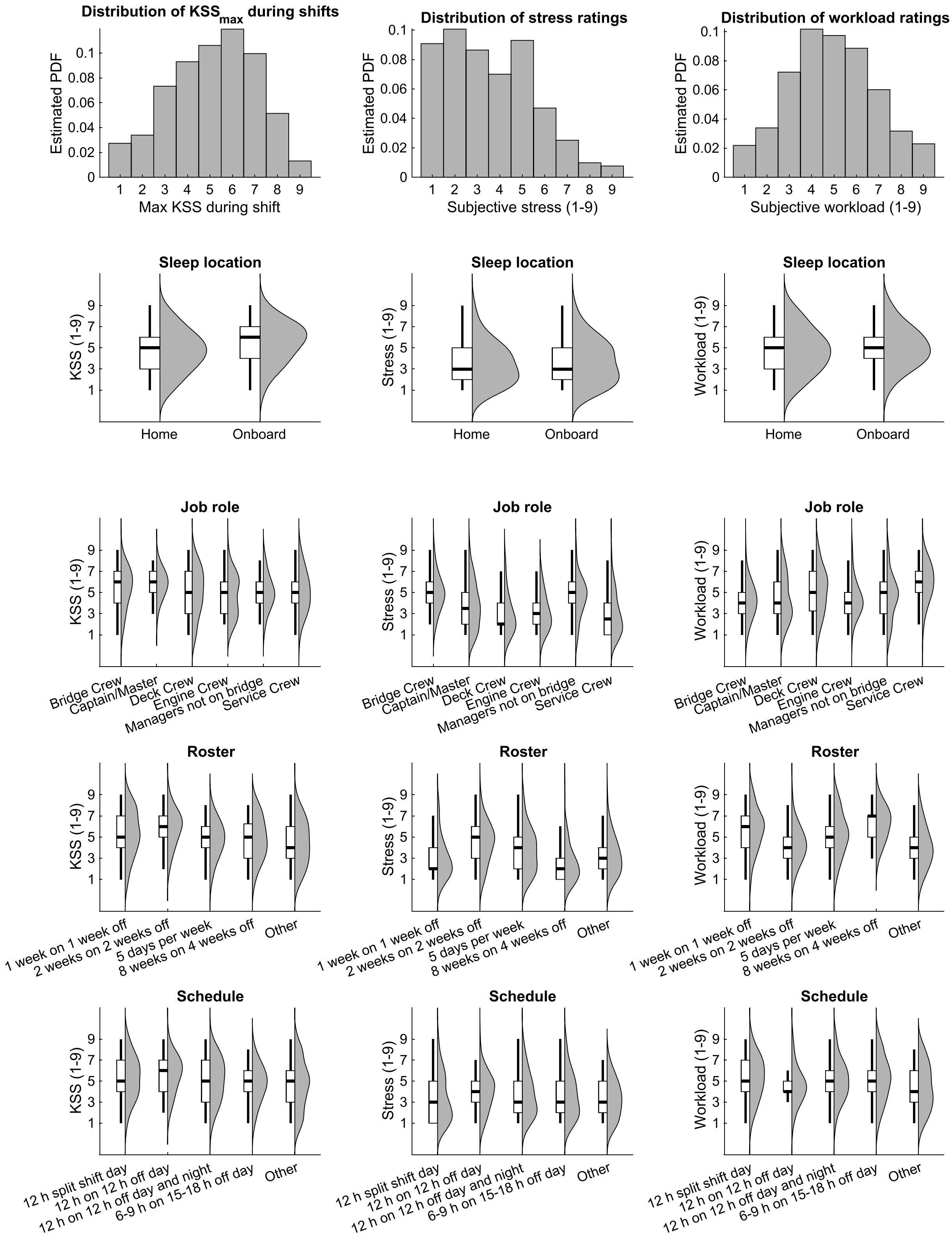


Figure 3. Probability density estimates and box plots of KSSmax (left), Stress (middle) and Workload (right) reported during shifts as a function of the work factors sleep location, working days, job role, schedule type, and roster type, respectively. The top row shows the overall probability density estimates in the full dataset. KSSmax = highest KSS score reported in a work shift.

Table 5. Mixed-effects logistic regression models of KSS ≥ 7 for the work factors. B is the estimated coefficient, t is the test statistic, p is the p-value, N is the number of observations, marginal R^2 is the variance explained by fixed effects, and −2LL is the log likelihood ratio.

	B	t	p	N	-2LL	R^2
Sleep location						
(Intercept)	−1.55	−5.90	<0.001*	564	1313.5	0.01
Sleep location	0.83	2.28	0.02			
Job role						
(Intercept)	−0.92	−1.47	0.14	564	1314.8	0.07
Bridge crew	0.04	0.05	0.96			
Deck crew	0.12	0.16	0.87			
Engine crew	−0.72	−0.82	0.41			
Non-bridge-managers	−0.80	−0.85	0.39			
Service crew	−0.32	−0.41	0.68			
Roster type						
(Intercept)	−1.80	−6.10	<0.001*	564	1317.9	0.09
1 week on 1 week off	1.31	2.38	0.02			
2 weeks on 2 weeks off	1.17	2.67	0.008*			
8 weeks on 4 weeks off	0.71	1.39	0.16			
Other	0.17	0.30	0.76			
Schedule type						
(Intercept)	−0.81	−2.30	0.02	564	1315.6	0.14
12 h on 12 h off day and night	−0.02	−0.02	0.98			
12 h split shift day	−0.02	−0.04	0.97			
6–9 h on 15–18 h off day	−1.00	0.48	0.04			
Other	−0.60	−1.04	0.30			

Significant effects are marked with *where the significance level is set to $p \leq 0.05$ ($p \leq 0.01$ after Bonferroni correction).

more often. Approximately 24% of KSS ratings on duty were 7 or higher, with 27% of work shifts having KSS ≥ 7.

The findings align with previous research indicating that fatigue is prevalent among seafarers and is influenced by work schedules and rosters. Studies by Grech (2016) and Jepsen et al. (2015) have similarly highlighted the impact of long working hours and shift work on seafarer fatigue. However, this study provides new insights into the specific effects of different roster patterns and schedules, particularly in ferry operations, which have been studied less often. It is notable that no particular job roles were identified as most at risk of fatigue.

Sleepiness increased with longer work hours across all groups, suggesting that time on task contributed to fatigue. Similar time-on-task effects have been found in cross-sectional surveys (Wadsworth et al. 2008), onboard longitudinal studies (Leung et al. 2006), and simulated work studies (van Leeuwen et al. 2013), consistently showing higher sleepiness/fatigue toward the end of work shifts compared to the beginning of the shift for seafarers.

There were no significant differences in sleep quantity, sleep quality, sleepiness, stress, and workload between participants sleeping on board and at home. This was somewhat unexpected since the onboard environment was assumed to be more tiring. It is possible that those going home to sleep had commute times, family responsibilities, social activities or similar that affected their sleep. One previous study investigating the effects of sleeping location on seafarer fatigue found excessive sleepiness in fishermen due to lack of sleep at sea as compared to home (Gander et al. 2008). It has also been identified that environmental factors such as noise, crew cabin conditions, and sea state impact sleep quality in seafarers and can explain differences between studies investigating the effects of sleep location (Kim et al. 2024). The physical work environment, including noise, vibration, fumes, and vessel motion, also impact the development of fatigue during the workday (Wadsworth et al. 2008). However, the lack of significant difference in sleep between those going home to sleep and those sleeping on board in the current work suggests that the impact of such on board factors is no greater than the impact of home-based factors such as commuting or family pressures.

Influence of Work Schedules

There were statistically significant associations between day-to-day schedules and sleep durations. Participants working 12 h split shifts had shorter sleep durations than the other groups. They also showed a different pattern in sleepiness across the day with a second peak in sleepiness in the afternoon, in addition to the peak at midnight. Their maximum KSS scores and proportion of shifts with high KSS were, however, not significantly different from participants working other schedules. Working split shifts generally results in a longer working day, which reduces the time available for sleep and recuperation. To mitigate the risk of fatigue, it should be ensured that the seafarers have sufficient time for sleep.

Previous research on the effects of work schedules on seafarer sleepiness and health has focused on watch-standing schedules such as the 4 h on 8 h off or 6 h on 6 h off watch systems (Dohrmann and Leppin 2017). The 6 h on 6 h off watch system has been associated with higher risk of excessive sleepiness than other watch systems studied, e.g. 4-h on–8-h off, 4-h on–4-h off and 12-h on–12-h off (Härmä et al. 2008; Lützhöft et al. 2010)., These 2-section or 3-section watch systems are used in the shipping industry and naval operations where 24 h operation is needed over extended periods of time (months) and generally require the same number of seafarers working day and night, across all days of the week. In ferry operations, the workload often varies across the day and between days of the week and operating schedules are adjusted accordingly. These watch systems are therefore not commonly used in ferry operations, which makes it difficult to generalize findings about the relationship between work schedules and fatigue from other maritime operations.

Night work has repeatedly been associated with reduced sleep and increased risk of fatigue in seafarers (Leung et al. 2006; Härmä et al. 2008; Lützhöft et al. 2010; Gregory et al. 2020). Night workers did not stand out as particularly affected by fatigue in this study, indicating that schedules and rosters are not the only factors that influence seafarer fatigue. The results from the diaries showed that sleepiness on duty was experienced by participants working all types of schedules. However, comparing sleepiness on duty between night shifts and day shifts within the subgroup of night workers showed that they were sleepier during night shifts than day shifts. Previous research has shown that there are considerable differences between individuals in how well they tolerate shift work (Härmä 1993). Sensitivity to fatigue is greatly influenced by an individual's chronotype, which reflects their preference for being active or sleeping at certain times of the day or night. In other professions, such as bus driving, personal preferences regarding schedules have been linked to stress, poor health, and negative psychosocial work conditions (Ihlström et al. 2017). Therefore, considering seafarers' individual preferences and characteristics, such as chronotype, in scheduling could help mitigate the risk of sleepiness on duty.

Influence of Roster Patterns

The type of roster pattern was significantly associated with sleep duration. Participants on an 8-week on/4-week off roster had notably shorter sleep durations, while those on a 1 week on/1 week off schedule had significantly longer sleep durations than participants with other rosters. These results might be confounded by the fact that most participants on the 8-week on/4-week off roster worked 12-h split shifts and/or served as service crew. Despite the longer sleep durations for those on the 1-week on/1-week off roster, they still faced a relatively high risk of reaching a KSS score of 7 or higher. This discrepancy could be attributed to the prevalence of night shifts within this roster type. One conclusion could therefore be that even when prioritizing sleep between shifts, night work remains a significant risk factor for on-duty sleepiness.

Sleepiness ratings throughout the day varied among participants on different rosters. Those on 8-week on/4-week off schedules experienced peaks in sleepiness during the early morning and afternoon, whereas participants on other rosters felt sleepiest around midnight. Additionally, participants on the 2-week on/2-week off roster had a higher proportion of shifts with KSS ≥ 7 and reported significantly higher stress levels than those on other rosters. However, their workload ratings were significantly lower compared to those on the 8-week on/4-week off and 1-week on/1-week off rosters.

It is evident that the relationship between work schedules, rosters, and fatigue is complex among this sample of seafarers. The duration for which participants had been working a specific roster before the study began was unknown. Given that data collection occurred over a four-week period, it is impossible to draw conclusions about the long-term effects of working different roster patterns for several months or years.

Influence of Job Roles

There were no statistically significant differences between different job roles regarding hours slept, sleep quality, and on-duty sleepiness. Previous research has not shown consistent results when investigating the relationship between job roles and fatigue. Comparisons of fatigue between officers (managers) and non-officers have varied depending on the population studied and the nature of their work tasks (Mansyur et al. 2021). However, there were some differences in stress and workload among job roles. Bridge crew and non-bridge managers reported higher stress levels than other roles on the muster list. Conversely, workload was highest among service crew, likely due to the continuous nature of their tasks. Unlike other crew members whose workload fluctuates throughout a voyage, with peak periods during port operations, service crew must attend to passengers for most of the voyage, potentially resulting in a greater overall workload. The relationship between workload and fatigue is complex since both high workload (overload, high demands) and low workload (monotony, boredom) can contribute to task-related fatigue (May and Baldwin 2009).

The specific stressors experienced by seafarers in different job roles were not investigated, but an explanation for the discrepancies in stress and workload could be related to differences in perceived job demands, job control, and support from supervisors (Dohrmann et al. 2020). Previous studies have found that psychological work factors, such as high job demands and low job control, contribute to fatigue among ferry workers (Dohrmann et al. 2020). Moreover, long-term stress has been identified as one of the strongest predictors of fatigue in bus drivers (Anund et al. 2016). High stress can impact sleep and influence the pattern of cortisol secretion, which in turn influences fatigue (Dahlgren et al. 2005). Prevention of fatigue in ferry operations could therefore include initiatives to reduce demands and increase control, such as involving seafarers in workplace decision-making and the planning of work schedules and rosters (Egan et al. 2007; Joyce et al. 2010). Social support has also emerged as a crucial job resource that can protect against fatigue in both ferry operations (Dohrmann et al. 2019) and shipping (Andrei et al. 2020).

Fatigue management remains a critical issue in the ferry industry, with current legislation and guidance proving insufficient. The Maritime Labour Convention 2006 (MLC2006) was developed to improve living and working conditions for seafarers, addressing aspects such as wages, contracts, and social security. However, its impact has been mixed, with some workers reporting minimal improvements since its enforcement in 2013 (Fotteler et al. 2018). To effectively address fatigue and enhance safety, a more robust regulatory approach, realistic staffing, and effective training are essential. Fatigue affects cognitive performance and increases the risk of accidents (Dohrmann et al. 2019; Azimi Yancheshmeh et al. 2021). Seafarers' fatigue has been identified as a key contributing factor in about 10% of all marine incidents and accidents (Acejo et al. 2018). In ferry operations, this not only endangers the safety of the crew but also puts passengers at risk.

Study Strengths and Limitations

Unlike most maritime fatigue studies that focus on long-distance shipping, this study addresses the under-researched ferry sector. One of the main strengths of this study is its real-world setting, with data collected during normal operations across multiple vessels and companies, thereby enhancing ecological validity. The combination of objective measures (Fitbit data) and subjective assessments (KSS, stress, workload ratings) over a four-week period provided a comprehensive evaluation of the seafarers' fatigue. These findings have direct implications for fatigue management policies in ferry operations.

However, the study has several limitations, including a relatively small sample size and the potential for self-reporting bias in sleep diaries and questionnaires. The cut-off at KSS ≥ 7 is supported by the literature whereas the stress and workload scales employed in the study did not have validated cut-off scores. Not all combinations of roster patterns and work schedules were represented in the sample, limiting the ability to isolate the effects of specific schedules or rosters. Technical issues with the web application and the Fitbit devices may have also affected data accuracy. These limitations should be considered when interpreting the results. Future studies should also investigate the potential influence of age, physical activity, gender, and other individual factors on fatigue in larger samples of seafarers.

While wrist-worn sleep trackers, including Fitbit, have similar accuracy to research-grade actigraphs (Haghayegh et al. 2019), sleep monitoring using Fitbit proved unreliable at sea. This was likely due to the motion of the vessel interfering with the wrist motion-based sleep scoring algorithm. Consequently, sleep duration for field trial participants who slept on board was manually calculated in this study, as the automated scoring system could not be used. There have been successful trials at sea with other commercially available devices, such as the Oura ring and ReadiBand (Kubala et al. 2024). It is evident that the use of wearable devices for objective monitoring of seafarers' sleep requires validation in a relevant maritime environment before commencing data collection.

Conclusions

On-duty sleepiness ratings showed that fatigue was widespread across job roles and work schedules among ferry workers, suggesting that mitigation strategies should target the entire workforce.

Insights from the current study can be used to advance existing fatigue management practices. The use of split shifts is not advised since they resulted in the least amount of sleep amongst the participants. The variability in the impact of different rosters highlights the complexity of fatigue; longer rosters of 8 weeks on/4 weeks off showed evidence of short sleep duration although it is possible that this is not directly due to the roster itself, and, those working 2 weeks on/2 weeks off and 1 week on/1 week off experienced the highest number of shifts with high subjective sleepiness (KSS ≥7).

Short sleep duration is only one contributing factor to fatigue. Future research is necessary to identify the key contributors to excessive sleepiness so that mitigation strategies can be appropriately targeted. Similarly, evidence of fatigue was found across all job roles and among those sleeping both on board the vessel and at home. The current study focused on sleep duration, a major cause of fatigue, stress, and workload. Future research should broaden this scope to include objective measurements of other factors contributing to fatigue, in order to identify differences between job roles. Given the variability in stress and workload, it is likely there will also be variability in other factors. Fatigue countermeasures should then be directly targeted towards the specific causes of fatigue.

Acknowledgments

The research team would like to thank the Department for Transport and each of the ferry operating companies and trade unions for their support and cooperation throughout this research, and all of the participants for taking part in this research. We would also like to thank Karl Miller and Evita Papazikou for assistance with data collection, Jiota Nusia and Iaco Kircher for assistance with data processing, John Axelsson for providing the sleep diary app, the steering board for their input and the advisory board (Nita Shattuck, Michelle Grech and Göran Kecklund) for their guidance during research design.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Funding

The work has received funding from the UK Department for Transport.

References

Acejo I, Sampson H, Turgo N, Ellis N, Tang L. 2018. The causes of maritime accidents in the period 2002-2016. Seafarers International Research Centre (SIRC).

Åkerstedt T, Anund A, Axelsson J, Kecklund G. 2014. Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. J Sleep Res. 23 (3):240–252. https://doi.org/10.1111/jsr.12158

Åkerstedt T, Gillberg M. 1990. Subjective and objective sleepiness in the active individual. Int J Neurosci. 52(1–2):29–37. https://doi.org/10.3109/00207459008994241

Andrei DM, Griffin MA, Grech M, Neal A. 2020. How demands and resources impact chronic fatigue in the maritime industry. The mediating effect of acute fatigue, sleep quality and recovery. Saf Sci. 121:362–372.

Anund A, Ihlström J, Fors C, Kecklund G, Filtness A. 2016. Factors associated with self-reported driver sleepiness and incidents in city bus drivers. Ind Health. 54(4):337–346. https://doi.org/10.2486/indhealth.2015-0217

Azimi Yancheshmeh F, Mousavizadegan SH, Amini A, Smith AP, Kazemi R. 2021. An investigation of the effects of different shift schedules on the fatigue and sleepiness of officers on oil tankers during cargo handling operations. Ergonomics. 64(11):1465–1480. https://doi.org/10.1080/00140139.2021.1928298

Behavioural Insights Team, Transport Research Laboratory. 2023. Understanding seafarer roster patterns and fatigue on vessels. Department for Transport.

Cohen J. 1988. Statistical power analysis for the behavioral sciences. Lawrence Erlbaum Associate.

Dahlgren A, Kecklund G, Akerstedt T. 2005. Different levels of work-related stress and the effects on sleep, fatigue and cortisol. Scand J Work Environ Health. 31(4):277–285. https://doi.org/10.5271/sjweh.883

Dohrmann SB, Herttua K, Leppin A. 2019. Fatigue in ferry shipping employees: the role of work-family conflict and supervisor support. BMC Public Health. 19(1). https://doi.org/10.1186/s12889-019-7954-z

Dohrmann SB, Leppin A. 2017. Determinants of seafarers' fatigue: a systematic review and quality assessment. Int Arch Occup Environ Health. 90(1):13–37. https://doi.org/10.1007/s00420-016-1174-y

Dohrmann S, Herttua K, Leppin A. 2020. Is physical and psychological work stress associated with fatigue in Danish ferry ship employees? Int Marit Health. 71 (1):46–55. https://doi.org/10.5603/IMH.2020.0011

Egan M et al. 2007. The psychosocial and health effects of workplace reorganisation. 1. A systematic review of organisational-level interventions that aim to increase employee control. J Epidemiol Community Health. 61:945.

Filtness A et al. 2024. Understanding seafarer fatigue in ferry operations. Department for Transport.

Fotteler ML, Jensen OC, Andrioti D. 2018. Seafarers' views on the impact of the Maritime Labour Convention 2006 on their living and working conditions: results from a pilot study. Int Marit Health. 69(4):257–263. https://doi.org/10.5603/IMH.2018.0041

Gander PH. 2005. A review of fatigue management in the maritime sector. Sleep Wake Research Centre. Massey University.

Gander P, van den Berg M, Signal L. 2008. Sleep and sleepiness of fishermen on rotating schedules. Chronobiol Int. 25(2–-3):389–398. https://doi.org/10.1080/07420520802106728

Grech MR. 2016. Fatigue risk management: a maritime framework. Int J Environ Res Public Health. 13(2):175. https://doi.org/10.3390/ijerph13020175

Gregory K et al. 2020. An evaluation of fatigue factors in maritime pilot work scheduling. Chronobiol Int. 37

(9–10):1495–1501. https://doi.org/10.1080/07420528.2020.1817932
Haghayegh S, Khoshnevis S, Smolensky MH, Diller KR, Castriotta RJ. 2019. Accuracy of wristband Fitbit models in assessing sleep: systematic review and meta-analysis. J Med Internet Res. 21(11):e16273. https://doi.org/10.2196/16273
Härmä M. 1993. Individual differences in tolerance to shiftwork: a review. Ergonomics. 36(1–3):101–109. https://doi.org/10.1080/00140139308967860
Härmä M, Partinen M, Repo R, Sorsa M, Siivonen P. 2008. Effects of 6/6 and 4/8 watch systems on sleepiness among bridge officers. Chronobiol Int. 25(2–3):413–423. https://doi.org/10.1080/07420520802106769
Ihlström J, Kecklund G, Anund A. 2017. Split-shift work in relation to stress, health and psychosocial work factors among bus drivers. Work. 56(4):531–538. https://doi.org/10.3233/WOR-172520
Jepsen JR, Zhao Z, van Leeuwen WM. 2015. Seafarer fatigue: a review of risk factors, consequences for seafarers' health and safety and options for mitigation. Int Marit Health. 66 (2):106–117. https://doi.org/10.5603/IMH.2015.0024
Johns MW. 1991. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep. 14 (6):540–545. https://doi.org/10.1093/sleep/14.6.540
Joyce K, Pabayo R, Critchley JA, Bambra C. 2010. Flexible working conditions and their effects on employee health and wellbeing. Cochrane Database Syst Rev. 2:CD008009.
Kerkamm F et al. 2022. Measurement methods of fatigue, sleepiness, and sleep behaviour aboard ships: a systematic review. Int J Environ Res Public Health. 19:120.
Kim S-J, Jeon T-Y, Lee Y-C. 2024. Impact of ship noise on seafarers' sleep disturbances and daily activities: an analysis of fatigue increase and maritime accident risk through a survey. Appl Sci. 14(9):3757. https://doi.org/10.3390/app14093757
Kubala AG et al. 2024. Advancing a U.S. navy shipboard infrastructure for sleep monitoring with wearable technology. Appl Ergon. 117:104225. https://doi.org/10.1016/j.apergo.2024.104225
Leung AW, Chan CC, Ng JJ, Wong PC. 2006. Factors contributing to officers' fatigue in high-speed maritime craft operations. Appl Ergon. 37(5):565–576. https://doi.org/10.1016/j.apergo.2005.11.003
Li M, Wang N, Dupre ME. 2022. Association between the self-reported duration and quality of sleep and cognitive function among middle-aged and older adults in China. J Affect Disord. 304:20–27. https://doi.org/10.1016/j.jad.2022.02.039
Lützhöft M, Dahlgren A, Kircher A, Thorslund B, Gillberg M. 2010. Fatigue at sea in Swedish shipping—a field study. Am J Ind Med. 53(7):733–740. https://doi.org/10.1002/ajim.20814
Mansyur M, Sagitasari R, Wangge G, Sulistomo AB, Kekalih A. 2021. Long working hours, poor sleep quality, and work-family conflict: determinant factors of fatigue among Indonesian tugboat crewmembers. BMC Public Health. 21(1):1832. https://doi.org/10.1186/s12889-021-11883-6
May JF, Baldwin CL. 2009. Driver fatigue: the importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. Transp Res Part F Traffic Phychol Behav. 12(3):218–224. https://doi.org/10.1016/j.trf.2008.11.005
Miyata S et al. 2013. Poor sleep quality impairs cognitive performance in older adults. J Sleep Res. 22(5):535–541. https://doi.org/10.1111/jsr.12054
Nakagawa S, Schielzeth H. 2013. A general and simple method for obtaining R2 from generalized linear mixed-effects models. Methods Ecol Evol. 4(2):133–142. https://doi.org/10.1111/j.2041-210x.2012.00261.x
Nittari G, Gibelli F, Bailo P, Sirignano A, Ricci G. 2024. Factors affecting mental health of seafarers on board merchant ships: a systematic review. Rev Environ Health. 39:151–160.
Oldenburg M, Jensen H-J, Latza U, Baur X. 2009. Seafaring stressors aboard merchant and passenger ships. Int J Public Health. 54(2):96–105. https://doi.org/10.1007/s00038-009-7067-z
Rüpke I, Athanassiou G. 2024. Contributing factors of fatigue on seagoing vessels. Z für Arbeitswissenschaft. 78 (4):469–491. https://doi.org/10.1007/s41449-024-00451-4
Shattuck NL, Lawrence-Sidebottom D, Matsangas P, Nicholson M. 2023. Awakening to the challenge of fatigue management in maritime transportation. In: Rudin-Brown CM, Filtness AJ, editors. The handbook of fatigue management in transportation. CRC Press. p 111–123.
Short MA, Agostini A, Lushington K, Dorrian J. 2015. A systematic review of the sleep, sleepiness, and performance implications of limited wake shift work schedules. Scand J Work Environ Health. 41(5):425–440. https://doi.org/10.5271/sjweh.3509
Sparks PJ. 1992. Questionnaire survey of masters, mates, and pilots of a state ferries system on health, social, and performance indices relevant to shift work. Am J Ind Med. 21 (4):507–516. https://doi.org/10.1002/ajim.4700210406
van Leeuwen WMA et al. 2013. Sleep, sleepiness, and neurobehavioral performance while on watch in a simulated 4 hours on/8 hours off maritime watch system. Chronobiol Int. 30(9):1108–1115. https://doi.org/10.3109/07420528.2013.800874
Wadsworth EJ, Allen PH, McNamara RL, Smith AP. 2008. Fatigue and health in a seafaring population. Occup Med (Lond). 58(3):198–204. https://doi.org/10.1093/occmed/kqn008