VIA MEDICA

Int Marit Health
2022; 73, 3: 150–161
10.5603/IMH.2022.0028
www.intmarhealth.pl

ISSN 1641-9251
eISSN 2081-3252

ORIGINAL ARTICLE

Impact of work exposure on cognitive performance in Faroese deep-sea fishers: a field study

Annbjørg Selma Abrahamsen[1, 2], Pál Weihe[1, 2], Wessel M.A. van Leeuwen[3], Fróði Debes[1]

[1]Department of Occupational Medicine and Public Health, The Faroese Hospital System, Tórshavn, Faroe Islands
[2]Faculty of Health Sciences, The Faroese University, Torshavn, Faroe Islands
[3]Department of Psychology, Stress Research Institute, Stockholm University, Stockholm, Sweden

ABSTRACT

Background: *This study examines the impact of work-related exposure on the cognitive performance of Faroese deep-sea fishers. Faroese fishing crews work long hours in demanding and noisy environments amidst highly uncertain and challenging weather conditions. These factors, together with compromised patterns of rest and sleep, are known to increase fatigue. Our aim was to study if changes could be measured in fishers' cognitive performance at the end of the trip when compared with the baseline measure at the beginning.*

Materials and methods: *Data was collected over 15 months (May 2017 to July 2018) from 157 fishers on 18 fishing trips which involved 202 investigative days on board. Questionnaires and six computerised cognitive tests: Simple Reaction Time, Numeric Working Memory, Corsi Blocks, Rapid Visual Information Processing, Digit Vigilance, and Card Sorting Test were used for data collection at the beginning and end of the trip. Differences between the outcomes on the two test points were analysed with one-way ANOVA comparing the performances at the beginning and end of the voyage, and two-way ANOVA to examine the interactive effect of chronotype and test occasions on the outcomes. Mixed models were used to test for the effects of predictor variables.*

Results: *Significant declines in cognitive performance were observed from the beginning to the end of the trip, with decreases in visuospatial memory and reaction times, and increases in cognitive lapses. Furthermore, slowing in response times was observed in the second half of the Digit Vigilance test when comparing the halves.*

Conclusions: *Declines in performance were observed from the start to the end of the trip. Furthermore, fishers performed significantly worse in the second half of some parted tests, and evening types seem less influenced by irregular work hours. These findings call for improving the safety of the vessels and their crew.*

(Int Marit Health 2022; 73, 3: 150–161)

Key words: fishers, fatigue, cognitive decline, Digit Vigilance, Simple Reaction Time, Visuospatial Memory, the Psychomotor Vigilance Tests

INTRODUCTION

The fishing industry in the Faroe Islands is the driving force of the economy, accounting for approximately 50% of its annual exports [1]. This vital enterprise, however, is heavily dependent on factors like vegetational growth and weather conditions for its sustainability. Its location in the North Atlantic Ocean continues to provide many challenges to the industry and its workers by way of inclement weather and rough seas.

Annbjørg Selma Abrahamsen, MSc, Department of Occupational Medicine and Public Health, Sigmundargøta 5, FO-100 Tórshavn, Faroe Islands, e-mail: annbjorg@health.fo

Received: 29.09.2022 Accepted: 30.09.2022

The cognitive and physical demands on the fishers of this island nation remain part and parcel of life as their job involves high levels of physical activity, repetitive movements, and manual material handling tasks. They need to be constantly alert to possible dangers, whether caused by weather, machinery or incidents that require prompt and appropriate responses. Furthermore, their workload and working hours are controlled by fishing seasons and the magnitude of the catch rather than the clock, often resulting in limited and fragmented sleep.

The International Maritime Organization (IMO) defines fatigue as: "a state of feeling tired, weary, or sleepy that may result from prolonged mental or physical work, extended periods of anxiety, exposure to harsh environments, or loss of sleep", its causes and consequences being widespread [2]. The most recognised causes of fatigue in fishers are poor quality of rest, excessive workloads, noise and fractious interpersonal relationships [3].

Life on board fishing vessels differs from other types of shift work. Fishers remain on board during free shifts, eating and sleeping under challenging conditions. Various factors influence sleep quality on board, e.g. noise, vibrations, cabin temperatures, alarms, sleeping facilities and time of day [4]. In addition, workplaces in motion result in higher energy use [5], and psychosocial stress factors such as insecure income and distance from family could increase fatigue. Fishing vessels are relatively small in comparison to merchant vessels, thereby increasing the impact of environmental factors [6].

Fishers have a higher accident rate than those who work on land and on merchant vessels [7, 8]. The accident ratio between land workers and fishers in the Faroe Islands is 1 to 4 [7], and fatigue has been found to be a contributory factor in 16% of critical vessel accidents in the maritime industry [9]. Several groundings and collisions are linked to fatigue [10], making it a significant contributor toward 33% of personal injuries/accidents in maritime operations [11]. In fact, long-term cognitive fatigue (14%) is said to be the largest single factor responsible for accidents [12].

Despite these disproportionately high accident rates within the fishing industry [7, 13], research offering direct objective measures of fatigue in fishers is limited. Thus, our primary aim was to study how fatigue influences fishers' cognitive functions; and specifically investigate whether changes in cognitive performance could be observed during the fishers' time at sea. As far as we know, ours is the first study to provide objective quantitative measures testing the effect of fatigue on cognitive function among fishers [14].

MATERIALS AND METHODS

PARTICIPANTS AND PROCEDURES

Data was collected by the first author on board four types of fishing vessels based on their different working patterns and the varying length of workdays. Common to all vessels was that they had only one crew with no regular periods of leave. Data was collected from 18 fishing trips over 15 months, resulting in 202 investigative days on board and 1,822 person-days. Most of the study happened in Faroese fishing waters, except for two trips in East Greenland and Icelandic territories, and lasted between 2 to 39 days, with a median of 9 days.

The study was conducted in compliance with the Declaration of Helsinki, and received prior approval from the Faroese Committee on Biomedical Research Ethics and the Faroese Data Inspection Agency J. no. 16/00230-13. All participants were requested to provide written consent before participation.

DATA COLLECTION

Data collection began at the beginning of the voyage when the fishers were expected to be most rested. They were assessed through questionnaires and a Computerised Mental Performance Assessment System (COMPASS software developed by Northumbria University in Newcastle).

QUESTIONNAIRES

Self-report questionnaires (paper and computer-based) were used to collect demographic data, physical and mental health information, and work history. The Karolinska Sleep Questionnaire (KSQ), with a 6-point Likert scale (1 = always, to 6 = never) [15] was used to measure sleep quality, the Multidimensional Fatigue Inventory (MFI-20), with 20 questions on a 5-point scale (1 = "yes, that is true" to 5 = "no, that is not true"), assessed fatigue levels in five dimensions [16], and the Cognitive Failure Questionnaire (CFQ), with a 5-point Likert scale (0–4) in three dimensions was used to measure fatigue and its effect on cognition [17].

MENTAL ASSESSMENTS ON COMPUTER ASSISTED TESTS

Fishers were given six computerised cognitive tests at the beginning and end of their trips. The testing was performed with COMPASS 5.0 which was installed on 10 computers. The tests were: Simple Reaction Time (SRT), assessing attention, Numeric Working Memory (NWM), assessing working memory, Corsi Blocks (CB), assessing visuospatial memory, Rapid Visual Information Processing (RVIP), assessing working memory and sustained attention, Digit Vigilance (DV), assessing attention and vigilance, and Card Sorting (CS), assessing higher cognitive functioning (Table 1).

Participants were provided with four pre-test sessions to familiarise themselves with the process and to flatten the learning curve. Test results gave objective measures

Table 1. Cognitive tasks completed at baseline, at beginning and end of the fishing voyage prior to resting

Task	Descriptor	Scoring	Domain
SRT	An upwards pointing arrow was displayed on the screen at irregular intervals. Participants had to respond as quickly as possible when they saw the arrow appear. 50 stimuli were presented. The task lasted 3 minutes.	RT [ms]	Attention
NWM	Six single target numbers were displayed on the screen, one at a time. Participants were required to memorise the numbers as they appeared. Once the target series was presented, numbers were displayed one at a time, and participants were required to indicate which number was presented previously or not. Three trials were completed.	Accuracy [%] and RT for the correct responses [ms]	Working memory
DV	A fixed number appeared on the right of the screen and a series of changing numbers appeared on the left of the screen. Participants were required to respond when the number on the left matched the number on the right. The task lasted 3 minutes.	Accuracy [%], RT for the correct responses [ms], and false alarms (numbers)	Attention and vigilance
RVIP	A continuous series of single digits was presented at the rate of 100 per minute. Participants were required to make a response when three consecutive odd or three consecutive even digits are displayed. The task took 3 minutes to complete.	Accuracy [%], RT for correct responses [ms], and false alarms (number)	Working memory and sustained attention
CB	Nine blue squares on a black background were displayed on the screen. Some blue squares changed to red and back to blue in sequence. Participants were required to remember the sequences. The task was repeated 5 times at each level of difficulty, with the sequence span increasing from 4 upwards until the participants could no longer correctly recall the sequences. Participants had to select the blocks in the same sequence in which they were presented.	Length of sequence remembered	Visuospatial memory
CS	Cards varying in type, colour, and number of figures on card were displayed on the screen. Participants had to match each card that appeared at the bottom of the screen to one of the four piles (numbered 1, 2, 3, 4) in the upper part of the screen. The cards were matched by selecting the pile to which they thought they belonged. Participants were not told how to match the cards but were told whether they were right or wrong each time. Participants were told that they would not be timed.	Once fishers successfully completed 10 consecutive correct sorts, the rule changed and they repeated the process until they successfully completed 6 sorts Scoring: Number of responses used to complete the test	Executive functioning and cognitive flexibility

SRT — Simple Reaction Time; NWM — Numeric Working Memory; DV — Digit Vigilance; RVIP — Rapid Visual Information Processing; CB — Corsi Blocks; CS — Card Sorting; RT — Reaction Time; ms — milliseconds

of the fishers' abilities on both occasions and made it possible to view changes in cognitive performance. Based on a test-retest design, results from the end of the trip were compared to those from the beginning. The baseline test was completed at the beginning of the trip (most often on the day following training), to allow for some rest after training. The completion of the test battery took from 19–24 minutes. The recommendation to use tests that gather as many stimuli in as short a time as possible (to avoid subjects turning passive) was followed [18, pp. 39–70]. At the end of the last shift, before resting, the fishers were re-tested with the same cognitive test battery. All tests and procedures performed at the beginning of the trip were repeated with the exception of the questionnaire being more focussed on the details of their current voyage.

For the SRT test, Reaction Time (RT's) < 150 milliseconds (ms) were registered as false starts, and RT's > 1000 ms were registered as major lapses. For the DV, RT's < 300 ms were registered as false starts, and RT's > 800 ms as no response.

STATISTICAL ANALYSES

All fishers were included in the analysis. ANOVA was used to test for group differences in the MFI-20, KSQ, and CFQ. The group differences of interest were "type of ship", "having a paid job at home", "chronotype", and "age". Since age is a continuous numeric variable, regression was used for the age variable.

This being a field trip, there were a few variables beyond our control such as test 'start and end time' and length of trip. Since we wanted to examine the exact change in performance between the two test points with ANOVA, which does not control for covariates, a linear mixed model was first defined using crew ID nested within vessel type as random intercepts to investigate whether the outcome variables (SRT and DV) were affected by the predictor variables. Additive predictor variables were: 1) Test-time: beginning/end of trip; 2) Chronotype: morning, neither morning or evening, or evening person; 3) Dummy variable: designating time of day using the following time points: 1 = 0000–0559, 2 = 0600–1159, 3 = 1200–1759, 4 = 1800–2359; 4) Age; 5) Occupational titles: captains, mates, engineers, cooks, deckhands and holdmen; 6) Length of trip in days; 7) Hours of work per day; 8) Hours of sleep in the preceding 24 hours of testing, and 9) Interaction between test time and chronotype. The variables that were found to significantly affect the test outcomes are listed in Tables 2 and 3. Thereafter, one-way ANOVA was used to examine changes in performance on the computerised cognitive tests conducted at the two test points divided into the five domains under investigation. The outcome matrices assessed in our analysis for the SRT and DV tests were: (1) mean RT in ms (= DVMean, and SRTMean, for mean on the DV and SRT tests respectively); (2) Optimal response times – approximately the fastest 10% of RT in ms (DVF10P and SRTF10P, respectively; (3) The approximately 10% slowest RT in ms (DVS10P and SRTS10P respectively); (4) The size of variation within the responses (DVSD and SRTSD, respectively), and for the SRT test (5) The number of major lapses – RT's exceeding 1000 ms (SRT > 1000 ms). Horne and Wilkinson (1985) [19] states that although training may reduce learning, on experimental testing it rarely wholly eliminates it. The authors were of the opinion that the results of the NWM and CS tests were influenced by skill acquisition; thus, only the main measures listed under "scoring" in Table 1 were used in these tests to minimise the risk of incorrect conclusions based on a potential learning effect [19, 20]. The accuracy per cent of the RVIP test was only 40%. It seems that the fishers found it too complicated, so the test was excluded. Since there is only one variable for the CB test, a paired t-test comparison was used to compare test results from the beginning and the end of the trip.

According to the "new effort" effect (change from one test to another), even severely sleep-deprived subjects may perform normally for a short time by increasing compensatory effort [21, p. 150]. Given the relatively short sub-tests, the participants could benefit from the shifts between tests. Therefore, the raw data from the SRT and DV tests were divided into halves, comparing the first half to the second half of the corresponding test to check for decline when the test became one of endurance (SRTBh and SRTEh, and DVBh and DVEh, respectively). The tests appeared in the following sequence: 1 = SRT, 2 = NWM, 3 = CB, 4 = RVIP, 5 = DV, and 6 = CS. The tests took approximately 3 minutes each to complete. Lastly, a two-way ANOVA test was run between the SRTMean and DVMean outcome variables to test for the effect of time of test in interaction with chronotype. The mixed model and the two-way analysis were run in R, and one-way ANOVA and t-test analyses were made in SPSS software 28 (IBM Corp., Armonk, NY, USA).

RESULTS

Of the 176 fishers working on ships, 157 participated in the study of which 156 (99.4%) were men. Five did not complete the questionnaire at the beginning. Details regarding participants from the four vessel groups are presented in Table 2.

From the analysis between the MFI-20, the CFQ and the KSQ with subscales (Table 2) and the group variables: "type of ship", "having a paid job at home", "chronotype", "job on board" and age, the following differences were found: Those who had a paid job at home scored higher on general fatigue F(1, 125) 6.44, p = 0.012, and a positive association was found between general fatigue and age (r = 0.22, n = 148, p = 0.01). Age also had a positive relationship with CFQ-distractibility (r = 0.035, n = 119, p = 0.041) and the KSQ-Sleep apnoea index (r = 0.07, n = 144, p = 0.002). For more details on means and standard deviation (SD) divided by vessel type see Table 2.

From the linear mixed models that were conducted between the SRT and DV outcome variables (to examine effects of the predictor variables), the ANOVA tests made on the models revealed that test time and age were the variables with the highest influence on the outcome, with only the outcome of the DVEhSD being affected by job type and length of the trip as additional variables (Tables 3 and 4).

A paired t-test revealed that the fishers remembered significantly longer sequences of 4.80 (1.67) on the CB test at the beginning when compared to the end of the trip 4.44 (1.96), t (152) = 2.780, p = 0.006 (Fig. 1).

No change was observed between the start and end tests from the assessment on DV tests. When comparing the halves, however, a few significant changes emerged. The results revealed an increase in DVhMean and in the DVhF10P in the second half of the test conducted at the beginning and end of the trip and the DVEhS10P in the end test (Table 5).

When comparing the SRT test results from two time points, only RT > 1000 ms showed a change, with more major lapses at the end of the trip.

Comparing the mean RTs of the first half of the test to the second half conducted at the beginning of the trip, the size of the SD and the SRT > 1000 ms differed between the halves. The fishers' had higher variation and fewer lapses in the second half of the test. From the end test, only SRT > 1000 ms differed between the two halves, and similar to the start test, fewer lapses were detected in the second half of the test. The results from the SRT variables are illustrated in Table 6.

From the two-way ANOVA tests (viewing the relationship between the outcome variables of SRTMean and DVMean and the interaction between test time and chronotype, respectively), it is clear that chronotype influences test outcomes (Fig. 2). Of the six analyses run on the "mean variables", an interaction effect of test-time and chronotype was observed on the DVMean variable (p = 0.007), with the difference being between the

Table 2. Demographic characteristics of the fishers, presented both per vessel group and all together

Baseline characteristics	Longliner fresh fish	Longliner freezer	Netting vessel	Trawler boat	Overall
Number of participants:	90	14	34	19	157
Captain	7	1	4	5	17
Officer	9	1	3	5	18
Engineman	8	1	4	4	17
Cook	7	1	4	2	14
Deckhand	49	8	19	3	79
Holdman	7	2			9
Number of trips in vessel groups	8	1	4	5	18
Number of active ships in fleet	9	4	5	7	25
Median trip length [days]	14.0 (3.2)	39 (0)	3.4 (2.3)	6.0 (2.6)	8.5 (8.6)
Total days of data collection in each vessel group	114	39	22	27	202
Mean workdays a year	199	189	187	204	196
Minimum days	15	39	50	100	15
Maximum days	320	340	300	340	340
Work experience as a fisher [years]	25.1 (14.1)	17.7 (18.2)	17.6 (16.2)	27.8 (15.2)	19.5 (16.3)
Nationality:					
Faroese	84	14	34	19	151
Danish	4				
Other non-Nordic	2				
Civil status:					
Married/co-habiting	30	7	20	12	69
In relationship	16	2	4		22
Single/widowed, divorced	42	5	11	7	65
Not answered	2				2
Education:					
No vocational education	43	10	13	11	77
Education specific to job	17	4	11	3	34
3–4 year practical or theoretical education			2		2
+4 years education	3		2		5
Other					1
Education not stated	25		6	5	36
Age [years]	42.3 (16.7)	36.3 (15.4)	41.8 (15.4)	46.33 (15.2)	42.1 (16.1)
BMI	26.3 (5.6)	27.9 (6.1)	25.7 (4.8)	29.0 (4.4)	26.7 (5.3)
Diurnal preference (1, extreme morning to 5, extreme evening)	3.3 (1.3)	3.3 (1.3)	3.1 (1.4)	2.4 (1.3)	3.2 (1.4)
Self-reported sleep need [min]	445.7 (82.5)	436.2 (84.5)	462.0 (76.2)	476.1 (153.3)	452.9 (93.6)
KSQ Overall	81.78 (12.56)	80.93 (11.70)	77.4 (18.34)	84.61 (10.01)	81.29 (13.63)
Sleep quality index	16.67 (4.53)	16.00 (5.19)	17.93 (3.12)	18.58 (3.61)	17.1 (4.28)
Non-restorative sleep index	12.48 (3.05)	12.36 (3.18)	10.97 (3.78)	12.32 (2.43)	12.14 (3.09)
Sleep apnoea index	15.18 (3.46)	14.29 (4.73)	13.57 (4.25)	15.42 (1.87)	14.81 (3.63)

→

Table 2 (cont.). Demographic characteristics of the fishers, presented both per vessel group and all together

Baseline characteristics	Longliner fresh fish	Longliner freezer	Netting vessel	Trawler boat	Overall
Sleepiness and fatigue index	22.54 (4.37)	23.93 (3.71)	22.62 (3.91)	22.58 (4.15)	22.69 (4.17)
MFI:					
General fatigue	12.1 (2.4)	13.0 (2.2)	11.8 (2.3)	11.2 (2.1)	12 (2.3)
Physical fatigue	9.9 (2.0)	9.4 (2.7)	9.1 (1.9)	8.7 (2.1)	9.5 (2.1)
Mental fatigue	9.4 (2.1)	8.6 (2.1)	9.4 (1.9)	8.8 (2.6)	9.2 (2.1)
Reduced activity	9.4 (3.2)	8.2 (2.7)	8.9 (3.3)	10.4 (3.1)	9.2 (3.1)
Reduced motivation	8.1 (2.7)	6.6 (2.3)	7.6 (2.5)	6.8 (2.1)	7.7 (2.6)
CFQ:					
Forgetfulness	13.8 (4.7)	12.3 (4.2)	12.8 (4.4)	12.7 (3.9)	13.2 (4.5)
Distractibility	12.9 (4.2)	12.2 (4.2)	12.7 (4.4)	11.8 (4.8)	12.6 (4.4)
False triggering	9.8 (4.1)	7.6 (4.7)	8.8 (4.1)	9.2 (4.1)	9.2 (4.2)
CFQ — overall	37.5 (12.6)	34.5 (13.7)	35.6 (11.9)	34.4 (13.7)	36.3 (12.5)

Means and standard deviations presented in parentheses, per vessel group and all together; BMI — body mass index; KSQ — Karolinska Sleep Questionnaire; MFI — Multidimensional Fatigue Inventory; CFQ — Cognitive Failure Questionnaire

Table 3. Depicts the significant effects of independent variables (fixed effects) on the models with the repeated Simple Reaction Time dependent variables

Dependent variable (repeated)	Independent variables (fixed effects)	Df	F	P-value
SRTMean	Vessel Age	(F=1, 134.93) (F=1, 135.7)	5.96 18.36	0.02 < 0.001
SRT F10P	Vessel Age	(F16, 247.0) (F1, 247.0)	2.24 16.01	0.005 < 0.001
SRTSD	Age	(F1, 136.0)	9.87	0.002
SRT Lapses > 1000 ms	Age Test time	(F1, 136.0) (F1, 137.0)	11.35 7.12	< 0.001 0.009
SRTBhMean	Age	(F1, 133.0)	29.22	< 0.001
SRTBhF10P	Age Test time	(F1, 132.0) (F1, 133.0)	26.55 5.42	< 0.001 0.02
SRTBhS10P	Age Test time	(F1, 132.8) (F1, 132.34)	16.96 11.59	< 0.001 < 0.001
SRTBhSD	Age Test time	(F1, 133.0) (F1, 134.0)	11.18 19.14	0.001 < 0.001
SRTBhRT > 1000 ms	Age Test time	(F1, 136.0) (F1, 137.0)	10.33 16.74	0.002 < 0.001
SRTEhMean	Age	(F1, 133.0)	8.42	0.004
SRTEhS10P	Vessel Test time	(F16, 121.0) (F1, 137.0)	1.85 8.40	0.03 0.004
SRTEhF10P	Age Test time	(F1, 132.0) (F1, 133.0)	14.83 10.66	< 0.001 0.001
SRTEhSD	Age Test time	(F1, 133.0) (F1, 134.0)	4.67 7.46	0.03 0.007
SRTEhRT > 1000 ms	Age Test time	(F1, 134.93) (F1, 135.7)	5.96 18.36	0.02 < 0.001

Non-significant models: Model 3, SRTS10P; Df — degree of freedom

Table 4. Depicts the significant effects of independent variables (fixed effects) on the models with the repeated Digit Vigilance dependent variables

Dependent variable (repeated)	**Independent variables (fixed effects)**	**Df**	**F**	**P-value**
DVMeanR^{T}1	Age	(F1, 124.54) (F2, 125.84)	15.20 6.96	< 0.001 < 0.001
DVF10PRT[2]	Age	(F1, 128.33)	29.23	< 0.001
DVS10PRT[3]	Age	(F1, 138.59)	11.70	< 0.001
DVBhF10PRT[7]	Age Test time	(F1, 132.45) (F1, 131.61)	30.97 12.74	< 0.001 < 0.001
DVEhMean[10]	Age Test time	(F1, 132.00) (F1, 133.00)	27.39 65.75	< 0.001 < 0.001
DVEhF10P[11]	Age Test time	(F1, 132.00) (F1, 133.00)	46.46 44.64	< 0.001 < 0.001
DVEhS10P[12]	Age Test time	(F1, 132.00) (F1, 133.00)	8.82 14.10	0.004 < 0.001
DVEhSD[13]	Job types Trip length days Chronotype Test time	(F5, 117.02) (F1, 224.70) (F2, 116.58) (F1, 195.69)	3.13 5.69 4.29 8.82	0.011 0.018 0.016 0.003

Models: 4 DVSDRT, 5 DVBhMeanRT, 8 DVBhS10PRT and 9 DVBhSD are non-significant. Model number is specified by superscript numbers; Df — degree of freedom

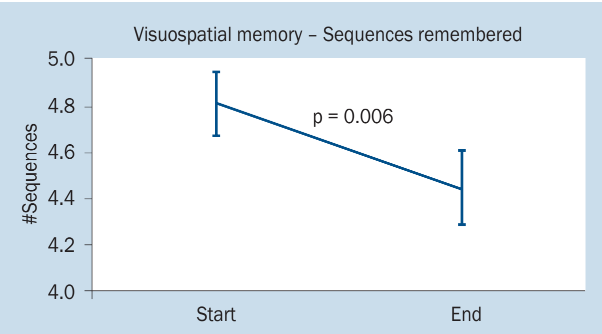

Figure 1. Paired t-test between the Corsi Blocks (CB) test conducted at the Start and End of the trip; Start — CB test at beginning of trip, End — CB test at end of trip

morning and evening types on the tests conducted at the end of the trip (p = 0.004). An effect of test time on the DVBhMean variable (p = 0.01), with the RT being slower at the end of the trip (p = 0.014) was also observed. Furthermore, both test time and chronotype as independent variables affected the DVEhMEAN variable, both at a level of p < 0.001. The fishers' performance was slower on the end test (p < 0.001), and the difference between chronotypes was found to be between morning and evening types (p < 0.001), neither morning or evening types, and evening types (p = 0.02). The effect on the SRTMean is not as strong, with the only group differences being observed between the chronotypes and SRTMean where the morning types' RT was significantly slower (p = 0.01). See Table 7 for the means and SD of the fishers.

Lastly, no differences emerged between the two test points on the NWM when comparing the accuracy of the responses in percent and RT of correct responses (RT in ms), or for the CS test. This is not surprising since the effect of

Table 5. Means, standard deviations and one-way analysis of variance of the Digit Vigilance (DV) Test, comparing reaction time at the beginning and end of the trip and comparing both halves of the tests conducted at the beginning and end of trip

DV measure	**1st half**	**2nd half**	**F ratio**	**P**
DVBhMean	498.41 (48.79)	511.87 (47.90)	5.065	0.025
DVBhF10P	411.25 (42.02)	422.13 (39.91)	5.118	0.024
DVEhMean	497.08 (50.32)	517.51 (50.30)	12.219	< 0.001
DVEhF10P	411.74 (43.04)	427.52 (45.27)	9.274	0.003
DVEhS10P	617.01 (66.86)	637.99 (63.01)	8.021	0.005

Standard deviations are presented in parentheses.

Table 6. Means, standard deviations and one-way analysis of variance of the Simple Reaction Time (SRT) Test, comparing reaction time at the beginning and end of the trip and comparing both halves of the tests conducted at the beginning and end of trip

SRT measure	Start/1st half	End/2nd half	F ratio	P
SRT lapses > 1000 ms	0.87 (1.43)	1.44 (2.58)	5.812	0.16
SRTBhSD	99.05 (63.08)	520.08 (168.54)	6.024	0.15
SRTBh lapses > 1000 ms	0.6 (1.04)	0.27 (0.71)	10.495	0.001
SRTEh lapses > 1000 ms	1.01 (1.87)	0.47 (1.08)	9.489	0.002

Standard deviations are presented in parentheses.

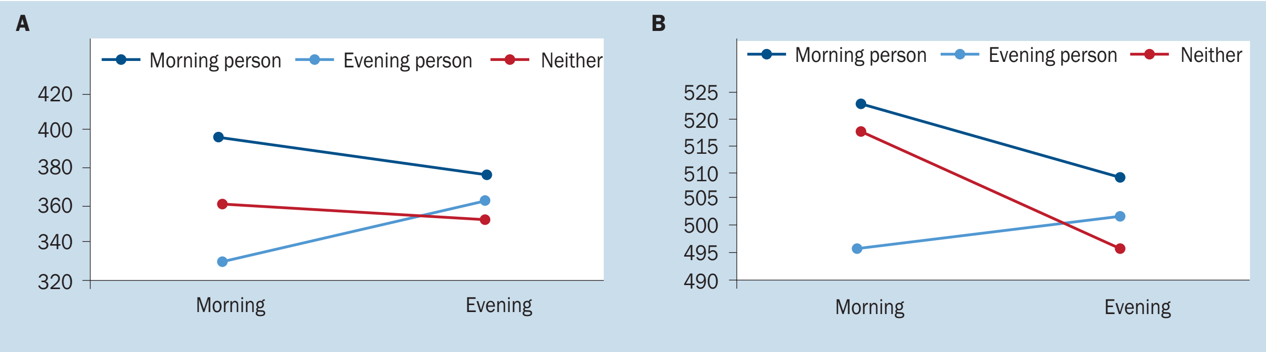

Figure 2. Chronotype and effect on performance on the Simple Reaction Time (SRT) and the Digit Vigilance (DV) interaction between the reaction time on the SRT (**A**) and DV (**B**) variables by test time (morning and evening) and chronotype

fatigue on performance has shown to vary between tests, with the highest impact observed from simple tests such as the SRT and the DV [22].

DISCUSSION

Despite major improvements in safety through education, training and technological advancement, human physiology and psychology are variables that have remained unchanged, and are the main challenges regarding irregular working hours [23, 24].

Unsurprisingly, fishers who also had paid jobs on land scored higher on general fatigue. Furthermore, age showed a positive relationship to general fatigue, distractibility on the CFQ, as well as sleep apnoea on the KSQ. The effect

Table 7. Means and standard deviations of the Simple Reaction Time (SRT) and the Digit Vigilance (DV) tests, full scale, comparing both halves of the start and end tests, respectively

Condition	DVMean	DVBhMean	DVEhMean	SRTMean	SRTBhMean	SRTEhMean
T1	502.2 (45.4)	498.4 (48.9)	496.84 (50)	357.9 (79.9)	362.4 (95.7)	367.8 (149.1)
T1:M	502.9 (43.7)	501.0 (46.7)	517.0 (54.2)	378.8 (85.3)	386.4 (96.8)	388.9 (95.4)
T1:N	492.3 (51.2)	489.4 (55.5)	506.0 (44.8)	354.4 (64.3)	347.2 (61.8)	354.8 (83.3)
T1:E	506.7 (42.5)	504.4 (48.1)	483.1 (43.6)	349.5 (82.9)	356.5 (107.3)	362.1 (199.4)
T2	505.7 (47.8)	512.1 (47.8)	518.2 (50.5)	360.8 (82.4)	356.2 (76.5)	364.1 (97.3)
T2:M	524.6 (46.0)	527.7 (46.3)	538.9 (48.7)	387.5 (90.3)	373.4 (81.2)	382.9 (95.0)
T2:N	517.2 (47.7)	512.0 (56.2)	526.5 (53.6)	356.3 (81.3)	367.3 (80.2)	352.6 (88.5)
T2:E	491.3 (49.4)	503.8 (43.8)	503.9 (45.3)	348.7 (78.0)	345.9 (73.9)	361.9 (107.2)
M	513.8 (47.4)	513.3 (48.8)	527.9 (52.4)	381.8 (87.8)	378.8 (89.4)	384.7 (94.9)
N	504.0 (50.6)	500.2 (56.4)	515.8 (49.8)	355.3 (72.2)	356.9 (71.2)	353.8 (84.9)
E	499.3 (42.5)	504.1 (45.9)	493.2 (45.3)	349.1 (78.0)	351.3 (92.4)	362.0 (160.8)

Standard deviations are presented in parentheses; T1 — time 1 (start of trip); T1:M — time 1, morning type; T1:N — Time 1, neither morning type or evening type; T1:E — Time 1, evening type; T2 — Time 2 (end of trip); T2:M — Time 2 — morning, T2:N — Time 2 — neither morning or evening type; T2:E — Time 2 — evening type of age on the test results was also confirmed by the mixed model where it (together with test time — start/end of trip) had the most consistent effect on outcome variables.

Cognitive testing of sleep-deprived people has demonstrated declined performance on psychomotor vigilance tests [23, 25, 26]. Our study confirms that a person's chronotype has an impact on the outcome of cognitive tests, depending on the time of day [27]. Furthermore, numerous studies have shown a relationship between long working days, insufficient sleep and decreased performance on such tests [28]. Even in cases of 4-hours on/8-hours off shifts, reduced alertness has been observed in the early mornings [29]. Our study also demonstrated significant reductions in visuospatial working memory at the end of the trip. Furthermore, reductions were observed between the 1st and 2nd half of the DV test (in mean RT and optimal response at the beginning of the trip), and in the mean RT and the fastest and slowest 10% of the reaction times in the end tests.

From the mixed model analysis, age and test time (beginning and end of trip) were the variables that most often influenced the results, and the vessel had an effect on the mean RT and the optimal response on the SRT test. As for the DVEhSD, the type of job, trip length and chronotype influenced the outcome together with test time. It was surprising that not more of the independent variables in the mixed model illustrated an effect on the outcome variable. However, although the test time is accounted for in the ANOVA, we must keep in mind (when interpreting outcome), that age and other significant effects in Tables 3 and 4 could have further influenced results.

The SRT test targeting attention (3-minute test), did not detect fatigue in the form of slowed RT but revealed cognitive decline by indicating significantly more major lapses (RT > 1000 ms) at the end of the test, possibly, due to lower sensitivity demonstrated in shorter tests [30]. These results are in accordance with the main measure of psychomotor vigilance tests and the most commonly used variable, which is not to assess the RT but to measure sustained attention and give numerical measures of sleepiness by counting the number of lapses in attention across tested occasions [27]. Furthermore, comparing the halves of the SRT tests, the SD increases in the second half of the test. This is in line with literature that supports a higher variance in fatigued individuals [31]. However, despite increased lapses from the beginning to the end of the trip, a decrease in lapses is seen in the second half of the tests, both at the beginning and at the end of the trip. One explanation might be due to it being the first test in the test battery. Possibly the fishers used a few test stimuli to get acquainted and ready for the test situation. Another explanation could be that compensatory alertness is mobilised in response to a state of mild fatigue that might result in an increased performance.

In a study testing sleep-deprived persons for 6 weeks on ten neuropsychological tests, only visuospatial memory and vigilance attention demonstrated significant cognitive decline. Our findings confirmed this by demonstrating a decline in visuospatial memory and RT at the end of the trip [32]. Overall, our study confirmed previous findings, with a slowing of RT and an increase in the number of lapses in the second half of the tests [23, 31].

Our study also challenges the assumption that fishers were rested on re-entry to vessels. The fishers usually got between 2 and 5 days off between each trip, and trawler crews even less. Assuming that more than half the fishers worked in shifts (splitting sleep into 1.5 to 4 periods per day), many may not have had time to adapt to natural sleeping rhythms on land, thus returning to the ship more fatigued, particularly if they wished to remain awake for family and social activities. It was also observed that many single young fishers desired to be socially active while on land. This alternate assumption is in line with the findings from an Icelandic study where fishers were most tired the first days at sea because they remained almost sleepless when home for just a few days [33, 34]. The current study assessed fishers on six tests of approximately three minutes each. Thus, the "new effort" effect could not be rejected. The "new effort" effect means that the fishers managed to mobilise much energy at the beginning, yet, when the test became one of endurance, fatigue manifested [21, p. 150].

The strength of this study is that it was conducted by the first author in the fishers' work environment during the entire voyage, reflecting work-life as it is, in contrast to laboratory studies. The use of objective measures to assess quantitative changes in the fishers' cognitive performance over two testings at the beginning and end of the trip is an additional strength since drowsy individuals have been found erroneous in evaluating their degree of fatigue-related cognitive impairment [23, 33]. By using this method, we can quantify the "after effect", with the difference reflecting how fatiguing the work has been. One likely explanation for not observing declines in more variables could be that the tests might have been too short and insensitive to measure the full extent of the fishers' fatigue. Short tests were chosen for this study to ensure economy of time and to prevent fatigue for participants. Basner et al. (2011) [30] suggest an increase in the sensitivity of 3-minute tests by reducing the threshold for lapses to 355 ms to get the same effect as in the standard 10-minutes the Psychomotor Vigilance Tests. However, we chose not to do this since the lowest DVMean RT was 394 ms and it would include about 50% of the SRTMean RT's. One could speculate that a higher threshold than 355 ms could serve a similar purpose in a future analysis.

Our findings indicate a chronically sleep-deprived group of workers. Chronic partial sleep deprivation can be defined as “subjects that are prevented from obtaining their usual amount of sleep within a 24-hour period” [35, p. 221]. This is also supported by actigraphy data from the same set of data published elsewhere, and the study shows that the mean sleep time for these fishers was less than 5 hours a day [36]. Being a field study, the researcher had limited opportunity to control the testing environment, e.g. time of testing and disturbance factors. Also, on the way out to sea, all fishers would usually be tested simultaneously, whereas at the end of the trip, only about half the fishers were tested at the same time, as the majority worked in shifts. However, it was obvious that some fishers were already fatigued at the beginning of the trip. The better performance in the first half of the test could, in addition to the test duration, demonstrate the “new effort” effect.

Results from the two-way ANOVA (showing the interaction-effect between test-time and chronotype, and the test time and chronotype as independent variables) confirm that it is a challenge to the human system when it comes to working irregular hours. Reduction in alertness can have widespread consequences for crew and vessel safety as it only takes a short moment of inattentiveness for an eventuality to occur, confirming other studies about how chronotype influences fishers’ alertness and speed on tests [37, 38]. Thus, knowledge of the crews’ chronotype is vitally important, especially when scheduling watches. Since there is increased risk of crew falling asleep during the early morning hours, extra manpower should be engaged on the bridge to increase safety. It is noteworthy that the evening types overall fared better on the tests and seemed less sensitive to long periods of work that are outside of standard daytime working hours.

Time spent on tasks has been shown to negatively affect performance as time increases [21]. The decrease in the second half could be a normal tiredness (time-on-test effect) affecting rested individuals, but we cannot rule out (especially in the DV starting around the 15th minute of testing) the presence of task-based fatigue. When this effect is detected, the individual tests are usually longer than the ones used in the current study [21, 23]. It is likely that the participants were more tired on the DV test than with the SRT test (1st in the test sequence). We doubt, however, that the extra 90 seconds of the DV test alone would be adequate explanation for all the change between the halves.

The results demonstrate that fishers’ performance on the cognitive tests declined between the two testings, with more major lapses on the SRT at the end test and slower reaction times in the second half of the DV test conducted at the beginning and end of the trip; deterioration in the crews’ visuospatial memory on the end test; as well as chronotype and the interaction between chronotype and the two test-points having an overall deteriorating effect on the outcomes.

CONCLUSIONS

The aim of this study was to examine the impact of fatigue on cognition amongst deep-sea fishers in North Atlantic waters. Despite the short duration of the various tests, the results demonstrate deterioration in attention, vigilance, and visuospatial memory in tests completed towards the end of the trip. Moreover, the finding that age and chronotype affected the results between the two testings (at start and end of trip) suggests that assigning shifts based on chronotype could be one way of reducing the risk of accidents. Furthermore, with the long working hours, being rested when returning to sea is imperative, as having a paid job on land might increase the risk of accidents due to increased general fatigue. Although the time of day the fishers performed the tests did not demonstrate a significant effect on any of the outcome variables, future studies should focus on further improving test times and test environments. Priority should be on fewer but longer tests to avoid the possibility of learning effects and the new effort effect. Although not possible with the current test battery, it will be beneficial for tests to appear in random sequence if more than one is to be conducted, to prevent the issue of sequential test effects.

The findings in this study demonstrate that fatigue is highly prevalent amongst this segment of workers, shedding light on its underlying reasons, as well as suggesting strategies that could be implemented to reduce the risk of potential accidents that could arise owing to this. More in-depth research in the field is imperative since lapses in attention and reduced response times in workers could result in more frequent and serious eventualities occurring on board vessels of this nature.

ACKNOWLEDGEMENTS

The authors would like to thank Rógvi Lydersen and Jonas Elias Larsen for their help with preparing graphs and tables, the deceased Jógvan á Høvdanum for involvement in data collection, Maria Skaalum Petersen and Turid Hammer for reading through the work and giving valuable advice, and Amaranie E. Goonetilleke for proofreading and editing. Furthermore, we want to thank Lis H. Magnussen and Jóhan Simonsen at the Faroese Fisheries Inspection (vorn.fo), for co-operation in getting in contact with the captains when ships arrived in harbour and made it possible to make arrangements for getting onboard the vessels. Lastly, we would like to show our gratitude to the fishers for participating in the study.

FINANCIAL SUPPORT AND SPONSORSHIP

This work was supported by the Faroese Research Council; the Fisheries Research Fund of the Faroe Islands; the Faroese Agricultural Foundation; the Faroese Union of Shipmasters and Navigators; The Faroese Marine Engineering Union; The Faroese fishermen Union; The Workers Union of *Kollafjørður*; and the Workers Union *Hæddin*.

Conflict of interest: None declared

REFERENCES

1. Faroese, Government. Hagstovan. https://hagstova.fo/fo/b%25C3%25BAskapur/uttanlandshandil/%25 C3%25BAtflutningur-av-v%25C3%25B8rum.
2. Jepsen JR, Zhao Z, van Leeuwen WMA. Seafarer fatigue: a review of risk factors, consequences for seafarers' health and safety and options for mitigation. Int Marit Health. 2015; 66(2): 106–117, doi: 10.5603/IMH.2015.0024, indexed in Pubmed: 26119681.
3. International Maritime Organisation. Fatigue factors in manning and safety. In: Fatigue Factors in Manning and Safety. Vol. A. 772; 1993: 7. https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.772(18).pdf.
4. Hansen JH, Holmen IM. Sleep disturbances among offshore fleet workers: a questionnaire-based survey. Int Marit Health. 2011; 62(2): 123–130, indexed in Pubmed: 21910116.
5. Breidahl T, Christensen M, Jepsen JR, et al. The influence of ship movements on the energy expenditure of fishermen. A study during a North Sea voyage in calm weather. Int Marit Health. 2013; 64(3): 114–120, indexed in Pubmed: 24072536.
6. Zhou Y, Daamen W, Vellinga T, et al. Impacts of wind and current on ship behavior in ports and waterways: A quantitative analysis based on AIS data. Ocean Eng. 2020; 213: 107774, doi: 10.1016/j.oceaneng.2020.107774.
7. Christiansen JM, Hovmand SR. Prevention of Accidents at Work in Nordic Fisheries – What Has Worked. 2017, doi: 10.6027/TN2017-509.
8. Roberts S, Williams J. Update of Mortality for Workers in the UK Merchant Shipping and Fishing Sectors. Vol 1976; 2005.
9. Raby M, Lee JD. Fatigue and Workload in the maritime industry. In: Stress, Workload, and Fatigue. In P.A. Ha. Mahwah. Lawrence Erlbaum Associates. New Jersey 2000: 566–578.
10. Strauch B. Investigating fatigue in marine accident investigations. Procedia Manufacturing. 2015; 3: 3115–3122, doi: 10.1016/j.promfg.2015.07.859.
11. Knauth P. Extended work periods. Ind Health. 2007; 45(1): 125–136, doi: 10.2486/indhealth.45.125, indexed in Pubmed: 17284884.
12. Wadsworth EJK, Allen PH, McNamara RL, et al. Fatigue and health in a seafaring population. Occup Med (Lond). 2008; 58(3): 198–204, doi: 10.1093/occmed/kqn008, indexed in Pubmed: 18310605.
13. Jensen OCC, Petursdottir G, Holmen IM, et al. A review of fatal accident incidence rate trends in fishing. Int Marit Health. 2014; 65(2): 47–52, doi: 10.5603/IMH.2014.0011, indexed in Pubmed: 25231324.
14. A Høvdanum AS, Jensen OC, Petursdóttir G, et al. A review of fatigue in fishermen: a complicated and underprioritised area of research. Int Marit Health. 2014; 65(3): 166–172, doi: 10.5603/IMH.2014.0031, indexed in Pubmed: 25471166.
15. Akerstedt T, Knutsson A, Westerholm P, et al. Sleep disturbances, work stress and work hours: a cross-sectional study. J Psychosom Res. 2002; 53(3): 741–748, doi: 10.1016/s0022-3999(02)003331, indexed in Pubmed: 12217447.
16. Smets EM, Garssen B, Bonke B, et al. The multidimensional fatigue inventory (MFI) psychometric qualities of an instrument to assess fatigue. J Psychosom Res. 1995; 39(3): 315–325, doi: 10.1016/0022-3999(94)00125-o, indexed in Pubmed: 7636775.
17. Broadbent DE, Cooper PF, FitzGerald P, et al. The cognitive failures questionnaire (CFQ) and its correlates. Br J Clin Psychol. 1982; 21(1): 1–16, doi: 10.1111/j.2044-8260.1982.tb01421.x, indexed in Pubmed: 7126941.
18. Dorrian J, NL R, Dinges D, Kushida CA. Psychomotor vigilance performance: Neurocognitive assay sensitive to sleeploss; pp. 39-70. In: Kushida CA, ed. Sleep Deprivation Clinical Issues, Pharmacology, and Sleep Loss Effects. Vol. 193. 1st ed. Marcel Dekker, New York 2005: 39–70.
19. Horne JA, Wilkinson S. Chronic sleep reduction: daytime vigilance performance and EEG measures of sleepiness, with particular reference to "practice" effects. Psychophysiology. 1985; 22(1): 69–78, doi: 10.1111/j.1469-8986.1985.tb01562.x, indexed in Pubmed: 3975321.
20. Tao M, Yang D, Liu W. Learning effect and its prediction for cognitive tests used in studies on indoor environmental quality. Energy Build. 2019; 197: 87–98, doi: 10.1016/j.enbuild.2019.05.044.
21. Lee M, Kleitman N. Studies on the physiology of sleep. II. Attempts to demonstrate functional changes in the nervous system during experimental insomnia. Am J Physiol-Legacy Content. 1923; 67(1): 141–152, doi: 10.1152/ajplegacy.1923.67.1.141.
22. Harrison Y, Horne JA. The impact of sleep deprivation on decision making: a review. J Exp Psychol Appl. 2000; 6(3): 236–249, doi: 10.1037//1076-898x.6.3.236, indexed in Pubmed: 11014055.
23. Van Dongen HPA, Maislin G, Mullington JM, et al. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep. 2003; 26(2): 117–126, doi: 10.1093/sleep/26.2.117, indexed in Pubmed: 12683469.
24. Hansen JH. Shift work in the offshore vessel fleet: circadian rhythms and cognitive performance. Dr thesis. 2012;39. https://brage.bibsys.no/xmlui//handle/11250/244989.
25. Dinges DF, Pack F, Williams K, et al. Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. Sleep. 1997; 20(4): 267–277, indexed in Pubmed: 9231952.
26. Tilley AJ, Wilkinson RT. The effects of a restricted sleep regime on the composition of sleep and on performance. Psychophysiology. 1984; 21(4): 406–412, doi: 10.1111/j.1469-8986.1984.tb00217.x, indexed in Pubmed: 6463172.
27. Barnett M, Zhao Z, van Leeuwen WMA. Project MARTHA: The Final Report. 2017(January), doi: 10.13140/RG.2.2.30339.30249.
28. Basner M, Dinges DF. Maximizing sensitivity of the psychomotor vigilance test (PVT) to sleep loss. Sleep. 2011; 34(5): 581–591, doi: 10.1093/sleep/34.5.581, indexed in Pubmed: 21532951.
29. van Leeuwen WMA, Kircher A, Dahlgren A, et al. Sleep, sleepiness, and neurobehavioral performance while on watch in a simulated 4 hours on/8 hours off maritime watch system. Chronobiol Int. 2013; 30(9): 1108–1115, doi: 10.3109/07420528.2013.800874, indexed in Pubmed: 23879695.
30. Basner M, Mollicone D, Dinges D. Validity and sensitivity of a brief psychomotor vigilance test (PVT-B) to total and partial sleep deprivation. Acta Astronautica. 2011; 69(11-12): 949–959, doi: 10.1016/j.actaastro.2011.07.015.

31. Doran SM, Van Dongen HP, Dinges DF. Sustained attention performance during sleep deprivation: evidence of state instability. Arch Ital Biol. 2001; 139(3): 253–267, indexed in Pubmed: 11330205.
32. Smith MG, Wusk GC, Nasrini J, et al. Effects of six weeks of chronic sleep restriction with weekend recovery on cognitive performance and wellbeing in high-performing adults. Sleep. 2021; 44(8), doi: 10.1093/sleep/zsab051, indexed in Pubmed: 33630069.
33. Olafsdóttir L. The relationship between fishermen's health and sleeping habits. Work. 2004; 22(1): 57–61, indexed in Pubmed: 14757907.
34. Ólafsdóttir L. Áhrif hvíldar á heilsu og öryggi sjómanna Rannsókn gerð á íslenskum sjómönnum: Á vegum Samgönguráðuneytisins Maí 2004 Solarplexus ehf. 2004: 1–97.
35. Web W. Partial and Differential Sleep Deprivation. In: Kales A, Lippincott J, eds. Sleep, Physiology and Pathology: A Synopsium. JB Lippincott, Philadelphia 1969: 221–231.
36. Abrahamsen A, Weihe P, Fróði D, et al. Sleep, sleepiness, and fatigue on board Faroese fishing vessels. 2022(December 2021): 347–362.
37. Deutsch J. The effects of time of day on cognitive performance in adolescents. J Clin Sleep Med. 2011; 7(3): 3–7.
38. van Leeuwen WMA, Pekcan C, Barnett M, et al. Mathematical modelling of sleep and sleepiness under various watch keeping schedules in the maritime industry. Marine Policy. 2021; 130: 104277, doi: 10.1016/j.marpol.2020.104277.