

BMJ Open Sleep quality of offshore wind farm workers in the German exclusive economic zone: a cross-sectional study

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ABSTRACT

Objectives To assess the quality of sleep of employees in the German offshore wind industry and to explore factors associated with poor sleep quality.

Design Web-based cross-sectional survey.

Setting Offshore companies operating in wind farms within the German exclusive economic zone.

Participants Workers with regular offshore commitments and at least 28 days spent offshore in the past year (n=268).

Outcome measures Sleep quality in the past 4 weeks, troubles falling asleep or sleeping through in the past 4 weeks, differences in sleep quality between offshore deployments and onshore leaves.

Results Having problems with sleep onset was reported by 9.5% of the respondents. 16.5% reported troubles with maintaining sleep three or more times per week. The overall quality of sleep was rated as very bad by only 1.7% of the participants. 47.9% of the workers reported their quality of sleep to be worse during offshore commitments than when being onshore. Higher levels of exposure to noise, vibrations and poor air quality were associated with sleeping troubles and poorer sleep quality. Sharing the sleep cabin with colleagues was associated with troubles sleeping through. No association was found for working in rotating shifts and for regularity of the offshore commitments.

Conclusions Workers in our study showed frequent sleep problems and poorer sleep quality offshore than onshore. Our results indicate that higher degrees of exposure to noise, vibrations and artificial ventilation are associated with poor sleep quality rather than organisational factors such as shift-work and type of working schedule. In view of the high demands of the offshore workplace and the workers' particular recovery needs, addressing sleep disorders should be part of any health and safety management strategy for this workplace.

INTRODUCTION

The generation of electric power from wind energy turbines placed far away from the coast—offshore wind energy—is considered to be a sustainable technology for producing energy with environmental benefits due to its low carbon emission. The development of offshore wind energy is, thus, the object

Strengths and limitations of this study

- Our study is one of the first to quantitatively assess the sleep quality and sleep troubles among workers in the offshore wind industry, which is a relevant issue in view of the physical and psychological demands related to this kind of work.
- We used well-established instruments to address sleep quality in the general population. The study design is cross-sectional; our findings must therefore be interpreted with caution and do not fulfil all causality criteria (eg, lack temporality).
- The study lacks of an external control group.
- The study shows factors associated with poor sleep quality of offshore workers which have not been described before, such as the type of cabin offshore.

of national energy transition strategies in many countries.^{1 2} By the year 2017, the global cumulative offshore power capacity amounted >14000 megawatts, which represent 14-fold the capacity available in 2007.³ Currently, offshore wind capacity is growing off the coasts of Germany, the Netherlands, the UK, Denmark, the USA as well as in China, Vietnam, South Korea, Japan and India.⁴

In Europe, and particularly in Germany, the installations are characterised by their remoteness, with an average distance from the coast of 23.5 nautical miles (43.5 km) for European offshore wind parks³ and of up to 67 nautical miles (125 km) for German installations in the North Sea.⁵ Due to this remoteness, offshore wind energy workers generally sleep far away from home during their offshore commitments. Indeed, although some workers travel from islands or the mainland to the installations, many workers live on service platforms or ships at the high sea during their offshore commitments. Working and living in offshore wind farms is associated with several different strains that may adversely affect the workers' sleep quality, that is, rotating shift work with overlength, shifts of 12 hours, lacking

boundaries between work and leisure spaces, poor quality of sleeping facilities, noise and poor air quality.^{6,7}

Sea workers in general (offshore, seafarers) are subject to high physical and mental strains, associated with high needs for recovery.^{8,9} Work in the offshore wind industry is physically (McDonough, submitted) and mentally demanding and is associated with high levels of stress, fatigue and needs for recovery.^{10,11} Thus, workers in the offshore wind industry might be particularly prone to experiencing the negative effects of poor sleep quality.

Poor sleep quality has been, on the long term, found to be associated with health problems, with higher incidence of disease and poorer quality of life.^{12,13} Sleep disturbances are associated with the incidence of sickness absence.¹⁴ In addition, poor sleep quality is associated with lower job performance and injuries at work with up to 13% of work injuries potentially attributable to sleep disorders.¹⁵ In the oil and gas offshore industry, sleep quality has been observed to worsen during 2-week commitments.¹⁶

The aim of our study was to assess the sleep quality of employees in the offshore wind industry in the German exclusive economic zone (EEZ) and to investigate the factors associated with poor sleep quality in order to identify opportunities for preventive action. Particularly, we addressed the question whether sleep quality differed depending on job characteristics (type of shift, commitment schedule), type of sleeping accommodation (single vs shared room), location of the accommodation (ship, platform), phase of the wind farm (under construction or in operation) and level of exposure to physical strains (noise, vibrations and poor air quality).

METHODS

Study design and population

We conducted a cross-sectional study. Between September 2016 and January 2017, we performed an online survey among employees working on offshore wind installations located in the German EEZ of the North and Baltic Seas. At the time of the survey, there were 22 wind farms either already in operation or under construction in this area,⁵ with estimated 5000–7600 employees directly or indirectly working on them and thus having regularly or irregularly offshore commitments.^{17,18} These represent our study's source population. In order to ensure that the collective had sufficient offshore experience, we restricted the sample to workers with regular offshore deployments or with a total of at least 28 days offshore during the past year if they were working on an irregular schedule. Females (n=28) were also excluded from further analyses, since they differed statistically regarding relevant sociodemographic characteristics, such as marital and parental status.

Recruitment

Participation in the survey was anonymous and voluntary. Recruitment was carried out by contacting occupational

physicians, health and safety managers and human resources departments of offshore companies operating in the German EEZ. Contact was established via telephone, email and regular mail providing information leaflets on the purpose and means of the study in both German and English. In addition, we promoted the study on relevant online platforms and forums of offshore workers and presented the study at the 'Round-table Maritime Safety Partnership', a regular meeting of key stakeholders organised by the German Offshore Wind Energy Foundation.¹⁹

Questionnaire

Access to the online questionnaire was possible through a URL and QR-code provided in all written information materials (leaflets, emails and social-media postings) used for recruitment. The questionnaire had two language versions, German and English. The first screen of the questionnaire provided information on the study purpose and required participants to provide consent by ticking the corresponding box ("I hereby confirm that I have read and understood the study information and data protection policy above. I agree to participate") prior to proceed with collection of further data. Termination of the survey was possible at any stage.

The questionnaire was piloted and refined with the help of offshore workers. Completion of the questionnaire—including topics and instruments not reported in this paper—required a median time of 24 min.

Sociodemographic variables

We collected data on gender, age, marital status ('single' or 'living in a relationship'), parental status ('children under 18 years living at home' or 'no children') and nationality ('German' or 'other').

Job characteristics

We collected data on offshore experience ('<1 year' to '1–3 years' to '>3 years'), occupation type ('technician', 'other', including site manager, catering, room service, quality management, paramedics, etc), offshore work schedule ('regular', including 14/14 day rhythms as well as other models, 'occasional commitments'), work shifts ('rotating shift', 'non-rotating shift'), project phase of the wind farm ('under construction', 'operation'), location of accommodations ('onshore', 'hotel ship', 'offshore platform', 'construction ship') and type of room ('single cabin', 'double cabin').

Physical strains

Participants were asked to self-assess their level of exposure to noise, poor air quality and vibrations during offshore deployments. Response options were on a five-point Likert scale with the categories 'always', 'often', 'sometimes', 'rarely', 'never/hardly ever' as reported previously.⁷

Sleep quality

The questions related to sleep quality are shown in the online supplementary additional material. Sleep

quality was assessed according to the method used in the 'German Health Interview and Examination Survey for Adults', a regularly conducted representative survey on health and health determinants among the German population carried out by the Robert Koch Institute—the federal governmental public health institute.²⁰ Participants were first asked (Question (Q)1 and Q2) to report the incidence of sleep disorders at sleep onset and sleep disorders regarding duration of sleep over the past 4 weeks on a four-point scale ('not at all', 'less than once a week', 'one to two times per week', 'three or more times per week').²¹ Participants were then asked (Q3) to rate their sleep quality during the past 4 weeks in a four-point scale with the categories 'very good', 'fairly good', 'poor', 'fairly poor', according to the component #1 of the 'Pittsburgh Sleep Quality Index', a widely used self-rated questionnaire to assess sleep quality with good internal homogeneity, consistency and validity.²² In addition, we asked participants to assess their sleep quality in the same way ('very good' to 'very bad') during both their offshore stays (Q4) and during onshore leaves (Q5). We ascertained the difference in sleep quality between the offshore deployments and the onshore leaves by assessing the agreement between the answers to Q4 and to Q5. The resulting variable 'difference in sleep quality offshore-onshore' had three values: 'sleep offshore worse', 'no difference', 'sleep offshore better'.

Reasons for poor sleep quality offshore

The questionnaire included a question about the reasons for reporting poorer sleep quality offshore. Participants were able to select one or more reasons and the question was open for the participants to report further reasons.

Statistics

Items left unanswered were treated as missing values and excluded from analysis (ie, no imputation was done for any variable). Descriptive statistics are reported as frequencies and percentages for categorical variables. Bivariate associations were explored with contingency tables (data not shown). Bivariate and multivariate ordinal logistic regression were run to take the ordering of the outcome variables into account.²³ The associations between organisational factors (working schedule, shift work), accommodation (location of the sleeping facilities, type of sleeping cabin) and environmental factors (phase of the wind farm, noise, vibrations, air quality and odours) with the outcome variables (overall sleep quality, troubles falling asleep, troubles sleeping through, difference in sleep quality offshore-onshore) were assessed in multivariate ordinal logistic regression models. Model #1 adjusted for age, nationality, offshore experience and time point of answering to the survey. Model #2 additionally adjusted for the factors related to work organisation, accommodation and environment found to be statistically significantly associated with the outcome variables in model #1. In model #3 (full model), all factors related to work organisation, accommodation and environment

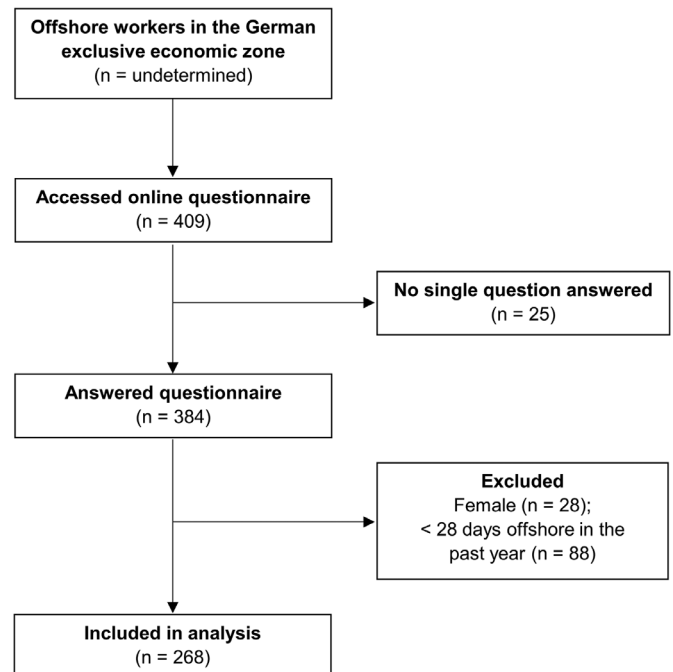


Figure 1 Study flow.

were added to model #1. The statistical significance level was set at $p < 0.05$. Statistical analyses were carried out using IBM SPSS Statistics V.23.0 (IBM, Armonk, New York, USA).

Patient and public involvement

Patients and public were not involved in the study.

RESULTS

In total, 384 persons responded to the questionnaire (figure 1), although not all of them answered all the questions of the survey. After application of the exclusion criteria, the final sample consisted of 268 male offshore workers (figure 1). Participant characteristics are shown in table 1. The majority of responders were German citizens (89.3%). The sample consisted mainly of experienced offshore workers with only 5.2% reporting <1 year of work experience in this environment. Approximately two-thirds of the responders were working on wind farms that were already operational (64.8%), while the rest were working on installations in the construction phase; 42.9% of the responders answered the questionnaire while being offshore and 27.6% had their last offshore commitment <1 month ago when answering the survey.

Half of these worked rotating shifts. Only 13.7% had accommodations at the mainland coast or at an island close to the wind farm during their offshore deployments, the majority slept either on platforms (44.1%) or in service vessels and construction ships (42.2%). Around one-third of the workers (37.0%) shared their sleeping facility (room or cabin) with at least one further worker.

Table 2 shows the answers to the questions regarding sleep quality. When comparing the agreement between

Table 1 Demographic and occupational characteristics of all participants and subgroups (only males with >28 days offshore)

Variable	Study population (n=268)	
	n	%
Age, years (n=268)		
20–34	116	43.4
35–49	122	45.5
≥50	30	11.2
Nationality (n=262)		
German	234	89.3
other	28	10.7
Offshore experience (n=267)		
<1 year	14	5.2
1–3 years	81	30.3
>3 years	172	64.4
Occupation (n=268)		
Management onshore (back office)	15	5.6
Management offshore/supervisor	83	31.0
Technician	131	48.9
Other	39	14.5
Work schedule (n=268)		
Regular, 14/14	198	73.9
Regular, other	35	13.0
Occasional commitments	35	13.0
Work shifts (n=263)		
Day shifts only	130	49.4
Night shifts only	1	0.4
Rotating shifts (day/night shifts)	132	50.2
Project phase of wind farm (n=268)		
Under construction	94	35.2
In operation	173	64.8
Accommodation (n=263)		
Offshore platform	116	44.1
Offshore hotel ship	67	25.5
Offshore construction ship	44	16.7
Island/mainland hotel/flat	36	13.7
Type of room (n=262)		
Single cabin	165	63.0
Double cabin	97	37.0
Time point answering the questionnaire (n=268)		
During an offshore commitment	115	42.9
Last offshore commitment <1 month ago	74	27.6
Last offshore commitment >1 month ago	79	29.5

responses to questions Q4 and Q5, 47.9% of the workers reported their quality of sleep to be worse during offshore commitments than when being onshore and

Table 2 Quality of sleep items

Item	n	%
Q1—troubles falling asleep in the past 4 weeks (n=232)		
Not at all	86	37.1
<1 time/week	78	33.6
1–2 times/week	46	19.8
≥3 times/week	22	9.5
Q2—troubles sleeping through in the past 4 weeks (n=237)		
Not at all	81	34.2
<1 time/week	74	31.2
1–2 times/week	43	18.1
≥3 times/week	39	16.5
Q3—sleep quality in the past 4 weeks (n=236)		
Very good	29	12.3
Fairly good	158	66.9
Poor	45	19.1
Very bad	4	1.7
Q4—sleep quality during offshore commitments (n=236)		
Very good	29	12.3
Fairly good	118	50.0
Poor	81	34.3
Very bad	8	3.4
Q5—sleep quality during onshore leave (n=239)		
Very good	63	26.4
Fairly good	155	64.9
Poor	21	8.8
Very bad	0	0

44.1% reported no differences. The difference between Q4 and Q5 was two or more categories worse in 7.6% of the respondents.

As shown in figure 2 and figure 3, more troubles falling asleep or sleeping through were reported by the workers currently offshore or with their last commitment <1 month ago when answering the survey. Again, bivariate logistic regression showed statistically significant differences with those currently or recently being offshore showing more troubles falling asleep (OR 2.24, 95% CI 1.32 to 3.83) and more troubles sleeping through (OR 2.01, 95% CI 1.19 to 3.39) in the past 4 weeks. Similarly, overall sleep quality in the past 4 weeks was more frequently rated to be very bad or poor among workers who were offshore or whose last offshore commitment was <1 month ago at the time of answering the questionnaire (figure 4), although the difference was not statistically significant (OR 1.82, 95% CI 0.99 to 3.32). For sleep quality during offshore commitments (figure 5), the difference between both groups was statistically significant in the bivariate ordinal logistic regression analysis (OR 1.90, 95% CI 1.10 to 3.29), with those being offshore or with their last offshore

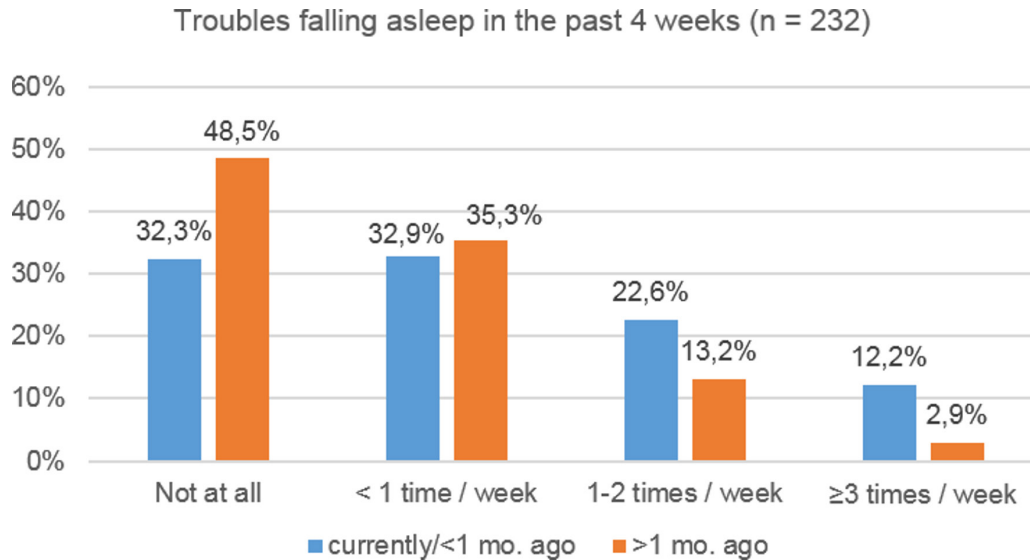


Figure 2 Q1—trouble falling asleep in the past 4 weeks according to point in time when answering the questionnaire.

commitment being <1 month ago reporting poorer sleep quality during the offshore commitments.

Factors affecting sleep quality

Among those showing a poorer quality of sleep offshore than onshore, 77.0% related this to noise, 65.5% to poor air quality or air-conditioning and 60.2% to limited privacy. Temperature and lighting conditions were a reason for worse sleep offshore only for about one quarter of (26.5% and 23.0%, respectively). Additional reasons were provided by 37.2% of the workers with factors related to the sleeping facilities (bed, room) being very common (13.2%) as well as difficulties with detachment after work (15.3%).

Table 3 shows the results of the multivariate analysis for the selected factors affecting sleep quality. Sharing the sleep cabin with other workers as well as noise, poor air quality and odours were statistically significant associated with higher incidence of sleep troubles in the past 4 weeks

(model #1). After further adjusting (model #2 and #3), only noise remained statistically significant associated with this outcome variable. Regarding sleeping through the night, being accommodated in a double-cabin was strongly associated (OR>2.0) with more troubles sleeping through in all models. Noise and air quality were also statistically significant associated with this parameter in model #1, but lost their statistical significance in the fully adjusted model.

All factors related to the working and living environment (noise, vibrations, odours, poor air quality/air conditioned) with the exception of the phase of the wind farm were associated with poor overall quality of sleep in the past 4 weeks, that is, the higher the level of exposition to the environmental factors the poorer quality of sleep was reported. When adjusted for the other environmental factors (model #2), noise and poor air quality remained statistically significant associated. In the fully adjusted

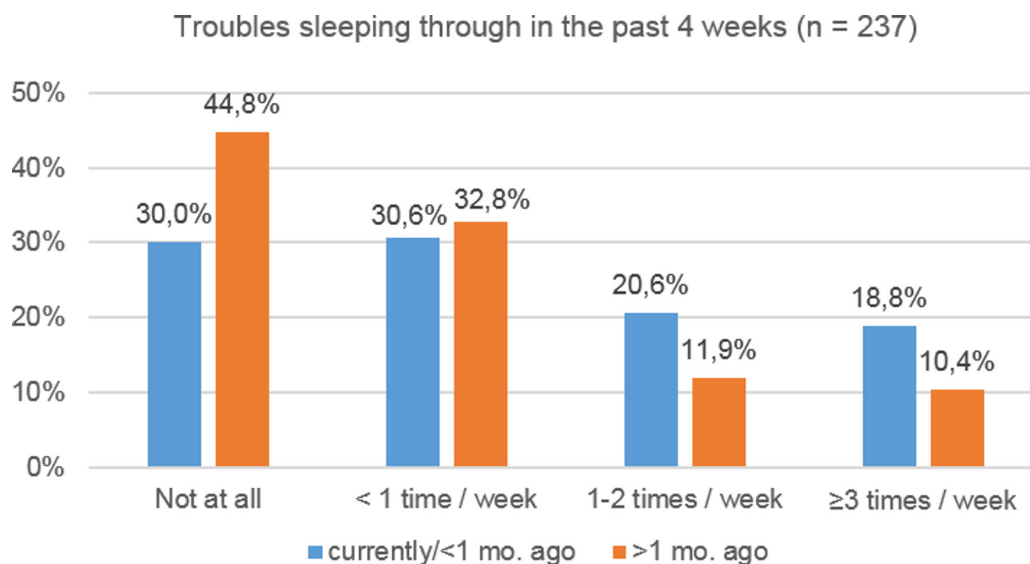


Figure 3 Q2—trouble sleeping through in the past 4 weeks according to point in time when answering the questionnaire.

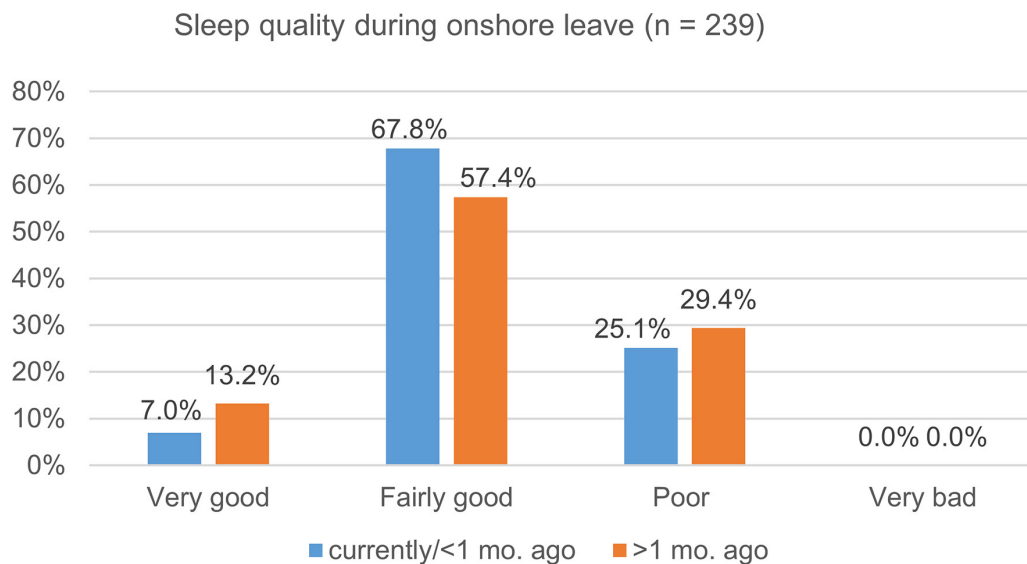


Figure 4 Q3—sleep quality in the past 4 weeks according to point in time when answering the questionnaire.

model (model #3), noise remained statistically significant associated with poor overall sleep quality in the past 4 weeks.

For the difference between the quality of sleep offshore and onshore, having the sleeping accommodation on an offshore platform was strongly associated with a worse quality of sleep offshore in all three models. In addition, noise was again also statistically significant associated with poorer quality of sleep offshore in all three models. Poor air quality and odours were found to be associated with this outcome variable in model #1, lost their significance after further adjusting (models #2 and #3).

DISCUSSION

To our knowledge, little is known about the quality of sleep in the offshore wind industry branch. Offshore workers perform strenuous physically and mental demanding and stressing work,^{7 9–11} with particularly high needs for

recovery.^{8 10} Thus, the quality of sleep is of particular relevancy for this job.

Our study reveals a comparably higher prevalence of sleep disorders among the offshore wind workers. Compared with the German general male population, the participants in our survey reported more frequently having sleep problems. In our sample, 9.5% had problems falling asleep three or more times per week compared with 8.6% of German males.²¹ The difference was slightly higher when looking at those currently or recently offshore (12.2% with problems falling asleep). Having sleep troubles three or more times weekly is considered to be a clinical relevant disorder.²¹

Offshore wind workers showed less problems maintaining sleep than the general male population. In our sample, 65.4% reported trouble sleeping through less than once weekly and 34.6% at least once per week compared with 62.5% and 37.5%, respectively, in the German health

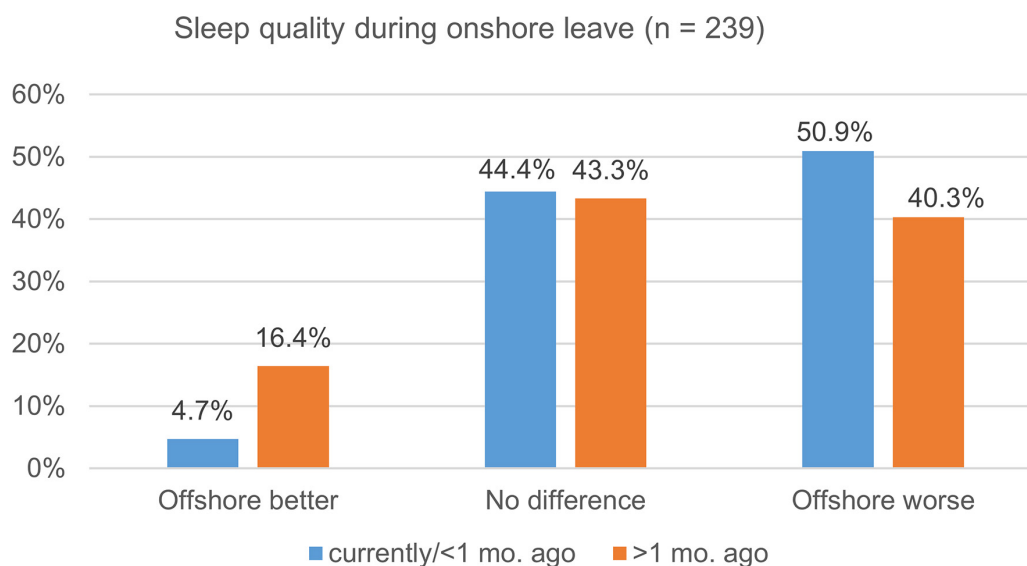


Figure 5 Q4—sleep quality during offshore commitments according to point in time when answering the questionnaire.

Table 3 Factors affecting quality of sleep

Factor	Model 1† OR (95% CI)	Model 2‡ OR (95% CI)	Model 3§ OR (95% CI)
Q1—troubles falling asleep in the past 4 weeks			
Work organisation			
Work schedule (ref.: regular deployments)	0.90 (0.45 to 1.79)	–	0.92 (0.43 to 1.93)
Rotating shift work (ref.: no shift work)	1.05 (0.64 to 1.75)	–	0.96 (0.48 to 1.92)
Accommodation			
Type of cabin (ref.: single cabin)	1.70 (1.03 to 2.81)*	1.51 (0.90 to 2.53)	1.56 (0.87 to 2.79)
Location of sleep accommodation (ref.: onshore)			
Offshore platform	1.46 (0.67 to 3.22)	–	0.91 (0.38 to 2.17)
Offshore hotel ship	1.58 (0.69 to 3.62)	–	1.12 (0.40 to 3.09)
Offshore construction ship	1.07 (0.44 to 2.62)	–	1.22 (0.27 to 2.45)
Working and living environment			
Phase of the wind farm (ref.: in operation)	0.84 (0.49 to 1.44)	–	0.94 (0.52 to 1.69)
Noise (ref.: never/hardly ever)	1.39 (1.06 to 1.84)*	1.16 (0.86 to 1.58)	1.30 (0.90 to 1.88)
Poor air quality/air conditioning (ref.: never/hardly ever)	1.12 (1.18 to 1.83)**	1.34 (1.06 to 1.69)**	1.36 (1.06 to 1.73)**
Odours (ref.: never/hardly ever)	1.45 (1.22 to 1.87)**	1.22 (0.92 to 1.61)	1.23 (0.93 to 1.63)
Vibrations (ref.: never/hardly ever)	1.16 (0.93 to 1.46)	–	0.86 (0.63 to 1.16)
Q2—troubles sleeping through in the past 4 weeks			
Work organisation			
Work schedule (ref.: regular deployments)	0.91 (0.46 to 1.80)	–	0.87 (0.42 to 1.81)
Rotating shift work (ref.: no shift work)	1.07 (0.66 to 1.73)	–	0.86 (0.44 to 1.71)
Accommodation			
Type of cabin (ref.: single cabin)	2.19 (1.32 to 3.62)**	1.98 (1.18 to 3.30)**	2.09 (1.18 to 3.70)*
Location of sleep accommodation (ref.: onshore)			
Offshore platform	1.94 (0.89 to 4.23)	–	1.35 (0.57 to 3.20)
Offshore hotel ship	1.81 (0.79 to 4.12)	–	1.35 (0.49 to 3.72)
Offshore construction ship	1.21 (0.42 to 2.47)	–	0.81 (0.28 to 2.39)
Working and living environment			
Phase of the wind farm (ref.: in operation)	0.78 (0.46 to 1.33)	–	0.68 (0.54 to 1.72)
Noise (ref.: never/hardly ever)	1.46 (1.11 to 1.91)**	1.10 (0.78 to 1.57)	1.12 (0.79 to 1.60)
Poor air quality/air conditioning (ref.: never/hardly ever)	1.43 (1.12 to 1.77)**	1.27 (1.00 to 1.59)*	1.22 (0.96 to 1.54)
Odours (ref.: never/hardly ever)	1.38 (1.08 to 1.78)*	1.16 (0.88 to 1.54)	1.13 (0.85 to 1.49)
Vibrations (ref.: never/hardly ever)	1.35 (1.08 to 1.70)**	1.18 (0.88 to 1.57)	1.24 (0.92 to 1.67)
Q3—sleep quality in the past 4 weeks			
Work organisation			
Work schedule (ref.: regular deployments)	0.57 (0.26 to 1.24)	–	0.63 (0.27 to 1.48)
Rotating shift work (ref.: no shift work)	1.01 (0.58 to 1.78)	–	1.08 (0.49 to 2.37)
Accommodation			
Type of cabin (ref.: single cabin)	1.33 (0.75 to 2.34)	–	1.28 (0.66 to 2.46)
Location of sleep accommodation (ref.: onshore)			
Offshore platform	0.97 (0.39 to 2.37)	–	0.60 (0.22 to 1.65)

Continued

Table 3 Continued

Factor	Model 1† OR (95% CI)	Model 2‡ OR (95% CI)	Model 3§ OR (95% CI)
Offshore hotel ship	0.95 (0.37 to 2.44)	–	0.62 (0.19 to 2.01)
Offshore construction ship	0.81 (0.30 to 2.22)	–	0.59 (0.17 to 2.06)
Working and living environment			
Phase of the wind farm (ref.: in operation)	0.70 (0.38 to 1.28)	–	0.79 (0.40 to 1.56)
Noise (ref.: never/hardly ever)	1.83 (1.32 to 2.54)***	1.73 (1.15 to 2.61)**	1.72 (1.13 to 2.62)*
Poor air quality/air conditioning (ref.: never/hardly ever)	1.44 (1.12 to 1.85)**	1.33 (1.02 to 1.75)*	1.32 (0.99 to 1.75)
Odours (ref.: never/hardly ever)	1.45 (1.09 to 1.95)*	1.14 (0.83 to 1.57)	1.16 (0.84 to 1.60)
Vibrations (ref.: never/hardly ever)	1.33 (1.02 to 1.74)*	0.91 (0.65 to 1.28)	0.94 (0.66 to 1.34)
Q4–Q5—difference in quality of sleep between offshore and onshore			
Work organisation			
Work schedule (ref.: regular deployments)	1.34 (0.65 to 2.76)	–	1.71 (0.77 to 3.81)
Rotating shift work (ref.: no shift work)	0.97 (0.58 to 1.64)	–	1.02 (0.48 to 2.16)
Accommodation			
Type of cabin (ref.: single cabin)	1.30 (0.76 to 2.22)	–	0.85 (0.47 to 1.60)
Location of sleep accommodation (ref.: onshore)			
Offshore platform	4.20 (1.77 to 9.95)**	3.86 (1.56 to 9.53)**	3.80 (1.48 to 9.79)**
Offshore hotel ship	1.80 (0.74 to 4.39)	–	1.46 (0.49 to 4.34)
Offshore construction ship	2.16 (0.83 to 5.58)	–	1.94 (0.61 to 6.24)
Working and living environment			
Phase of the wind farm (ref.: in operation)	0.87 (0.50 to 1.54)	–	1.09 (0.58 to 2.05)
Noise (ref.: never/hardly ever)	1.61 (1.19 to 2.16)**	1.49 (1.00 to 2.19)*	1.57 (1.05 to 2.34)*
Poor air quality/air conditioning (ref.: never/hardly ever)	1.34 (1.06 to 1.69)*	1.12 (0.87 to 1.45)	1.13 (0.87 to 1.47)
Odours (ref.: never/hardly ever)	1.47 (1.12 to 1.92)**	1.15 (0.85 to 1.56)	1.16 (0.85 to 1.57)
Vibrations (ref.: never/hardly ever)	1.25 (0.99 to 1.59)	0.98 (0.71 to 1.35)	0.94 (0.68 to 1.31)

*p<0.05, **p<0.01, ***p<0.001. Bold characters indicate statistically significant results.

†Adjusted for age, nationality, offshore experience, time point of answering the survey.

‡Adjusted for age, nationality, offshore experience, time point of answering the survey and significant factors in model 1.

§Adjusted for age, nationality, offshore experience, time point of answering the survey and all other factors related to work organisation, accommodation and working and living environment as listed in the first column.

Ref., reference category.

survey.²¹ Due to presence of environmental sleep disruptors, one would, however, expect the opposite.

Overall quality of sleep in the past 4 weeks (which may include both offshore and onshore periods) was comparable to that of the general male population with 19.1% reporting poor and 1.7% reporting very bad overall sleep quality in our sample compared with 18.2% and 1.7% respectively.¹⁹ However, the difference was, again, greater when focusing on the answers from workers currently being or having recently been offshore (22.0% poor overall sleep quality and 1.8% very bad overall sleep quality).

In summary, the workers in our study rated their quality of sleep to be worse during offshore deployments than when being onshore. These findings are consistent with previous research from the offshore oil and gas industry,

which also showed a high prevalence of sleep disturbances²⁴ among those workers and a better sleep quality and sleep duration during onshore leaves as compared with offshore working periods.^{16 25} In general, shift work is a well-known sleep disruptor,²⁶ and it has been reported to be associated with poorer sleep quality among offshore workers in the oil and gas industry.²⁴ In addition, long shifts and working overtime (ie, 12 hours or more) also negatively affect sleep quality in these workers.^{25 27} Surprisingly, in our sample we did not find any association between the shift schedule (day shifts only vs rotating night and day shifts) and the prevalence of sleep disorders or the quality of sleep, although shifts in the offshore wind industry are mostly 12 hours shifts. Similarly, no association was found with the type of work schedule (regular offshore commitments vs irregular deployments). This

might be due to the fact that the participants were relatively young and, thus, they might tolerate shift work better.^{28 29}

The most important associations we found were related to the working and living environment offshore. The multivariate analysis showed that exposure to noise was consistently associated with poorer sleep quality offshore, overall poor sleep quality and troubles maintaining sleep in multivariate analysis, underlining the perception of the workers themselves when asked for the reasons for poor sleep quality. Noise results from several sources in the offshore environment. Part of the noise is related to the works being done on shift system while some staff is resting. In addition, noise also results from the operation of ventilation, power generation, etc in the service platforms and ships. Strategies to reduce noise need to consider the different sources of noise, requiring both behavioural (eg, cohabitation rules) and technical interventions (eg, better isolation). Finally, wind turbines itself produce noise, which has been identified as disturbing for the sleep of people living close to wind mills.³⁰

Vibrations, odours and poor air quality were also associated with poor sleep quality and sleep disturbances in our study, although less consistently than noise. Dry air has previously been associated with poorer sleep quality, while higher humidity in air has been proposed to improve sleep quality.³¹ Planners of offshore wind installations need to be aware of these factors, since they can probably be better addressed with technical solutions which might be more difficult to implement when the installations are already in operation. The location of the sleeping accommodation on a platform compared with accommodation on the mainland was only associated with one of the outcomes (poorer sleep offshore), although it was the strongest association (OR 3.80, 95% CI 1.48 to 9.79). This underlines the notion that the above-mentioned lack of separation between workplaces and accommodations can lead to exposure to the detrimental factors (eg, noise) beyond the own working times into the rest phases.

Our results indicate that the environmental factors influencing sleep quality, prevalence of troubles with sleep onset and maintaining sleep are present in all locations on sea (ships, platforms). This is consistent with our previous observation of high levels of exposure to noise and vibrations (>50% of participants reporting being either always or often exposed to them⁷), which are probably over the levels of exposure seen among German high-skilled manual workers or within the construction and transportation sector.³² In general, our findings are in line with previous studies, which have found noise, vibrations and cabin environment (eg, humidity, temperature) to be relevant sleep disturbers among offshore workers in the oil and gas industry as well as among seafarers.^{33 34}

Another important reason for sleep disturbances reported by the workers was the perception of limited privacy during the offshore deployments. We have already described the issue of constrained privacy in a qualitative study recently published.⁶ In the multivariate

analysis, sleeping in shared cabins was found to be associated with troubles falling asleep and sleeping through compared with having a single cabin. Sharing the room with a colleague surely contributes to the perception of lack of privacy and, in addition, may affect the sleep quality because of additional noises. To our knowledge, the association between the types of sleep accommodation (eg, single vs double cabin) and sleep quality has not been described before in the offshore setting.

Limitations

The main limitation of our study is its cross-sectional design, which prohibits the establishment of sound causal links in the associations observed.

Recall bias may also have been a problem concerning the reported quality of sleep during offshore deployments and onshore leaves, since not all respondents completed the survey at the same time. Indeed, 42.9% of the respondents answered the questionnaire while being offshore. We observed a tendency to report poorer quality of sleep in all outcome variables among those workers who were currently or had recently been offshore at the time of answering the survey (see figures 2-5). This indicates that those answering the questionnaire after longer onshore periods may recall sleep quality differently from those being currently offshore. We accounted for this by statistically adjusting for the time point of answering the questionnaire in all three multivariate models. Thus, we do not expect recall bias to relevantly affect our results regarding the factors associated with poorer quality of sleep.

Another limitation of our study is the lack of an external control group, which would have allowed to address the issue of observation bias (ie, the influence on the response behaviour due to the fact of being observed). Thus, we cannot draw any conclusions on whether the frequency of sleep disturbances is higher among offshore workers than among other shift workers.

Finally, as discussed elsewhere in detail,⁷ due to the lack of sound data on the workforce in the offshore wind energy industry, it is not possible to address whether the respondents to our survey are representative of this population (eg, regarding experience, nationality, etc). In addition, we cannot rule out that our participants are those caring more for their health. In case of such self-selection, it is difficult to predict the direction of bias imposed to our data. On the one side, higher health awareness might be associated with higher awareness regarding troubles, thus, our study overestimating the frequency of sleep problems. On the other side, higher health awareness could be associated with better sleep hygiene and, thus, less sleep problems. In the latter case, our study would have underestimated the real dimension of sleep disorders offshore. Since we excluded female employees, our results are only applicable to the male subgroup under the limitations mentioned above.

The use of SurveyMonkey for conducting our survey could raise concerns regarding data protection issues, since the tool implies storage of personal information

(eg, age, marital status, children, offshore experience, etc) in the USA. The tracking of particular individuals is, however, not possible, since we did not ask for the name of the company, the name of the installation nor its location. In addition, age was recorded on categories of 5 years.

Implications for clinicians and policy makers

Our findings reveal that sleep problems and poor sleep quality are common among workers in the offshore wind industry. This finding is of particular relevancy since the offshore job in the wind industry is particularly demanding.^{7 10 11}

Although offshore wind workers often perform work in rotating shifts, this does not seem to affect the quality of sleep in this group. In our study, we rather found environmental factors (noise, vibrations, indoor air quality and accommodation in shared cabins) to be associated with sleep disturbances and poorer sleep quality during offshore deployments. Such factors should, therefore, be considered in the planning and construction of future offshore housing facilities and service vessels in order to minimise their detrimental influence on the sleep quality of offshore workers. Indeed, new-generation service vessels already provide a better housing environment with reduced noise and vibrations.³⁵ However, we think that policy makers and regulators could help achieve the goal of building better facilities by enhancing or modifying the requirements and standards for the licensing of new offshore installations and housing facilities. Future facilities should overcome the current shortcomings in the accommodation of offshore workers.

Since poor sleep is well known to be associated with safety risks,¹⁴ good sleep is of special relevancy in a work place in which errors or accidents may have fatal consequences for the workers, their colleagues and also for the installations.

CONCLUSIONS

Offshore wind workers reported frequent sleep problems and almost half of them rated their sleep quality offshore to be worse compared with their sleep quality onshore. Our results indicate that higher degrees of exposure to noise, vibrations and artificial ventilation are associated with poor sleep quality offshore rather than organisational factors such as shift-work and type of working schedule. In the view of the high demands of the offshore workplace and the workers' particular recovery needs, addressing sleep disorders should be part of any health and safety management strategy in the offshore wind industry.

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statistical analysis and wrote the first draft. All authors (MVG, JM, SM, VH, AMP) contributed to the interpretation of data, provided input on the first draft and revised the manuscript.

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