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BMJ Open

The working conditions and health of offshore wind park workers – a cross-sectional study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-020157
Article Type:	Research
Date Submitted by the Author:	17-Oct-2017
Complete List of Authors:	Velasco Garrido, Marcial; Universitatsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Mette, Janika; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Mache, Stefanie; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Harth, Volker; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Preisser, Alexandra; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Occupational and environmental medicine
Keywords:	offshore, job demands, subjective health complaints, sleep quality

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Title: The working conditions and health of offshore wind park workers – a cross-sectional study.

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Subject heading: Occupational and environmental medicine

Keywords: offshore, job demands, subjective health complaints, sleep quality

Word count: 4,883

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Abstract

Objectives: To assess the working and living conditions, as well as the subjective health status of employees in the German offshore wind industry.

Design: Web-based cross-sectional survey.

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

Participants: 384 offshore workers completed the survey. Female workers and workers with less than 28 days offshore in the past year were excluded from further analysis. Final sample: 268.

Outcome measures: working and living conditions, self-rated health and health complaints, sleep quality.

Results: Working conditions differed depending on the phase of the wind park. Technicians were more often exposed to ergonomic strains than employees of other occupations (RR 2.21; 95% CI 1.53 to 3.18 for twisted upper body work; RR 2.29; 95% CI 1.28 to 4.09 for overhead work, and RR 1.76; 95% CI 1.29 to 2.40 for carrying heavy loads). Technicians and mechanics also showed a higher risk of shoulder pain (RR 1.44; 95% CI 1.02 to 2.05), neck pain (RR 1.43; 95% CI 1.10 to 1.85), back pain (RR 1.41; 95% CI 1.10 to 1.79), and arm pain (RR 2.31; 95% CI 1.36 to 3.92) when compared to workers of other occupations. Sleep quality while offshore was reported to be worse than while onshore by 47.9%. Sharing a cabin with other colleagues was associated both with troubles falling asleep (RR 1.63; 95% CI 1.10 to 2.41) and with problems sleeping through the night (RR 1.55; 95% CI 1.02 to 2.19).

Conclusions: Workers on offshore wind farms comprise a heterogeneous group, including a wide variety of occupations, job tasks, and work schedules. The degree of

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exposure to detrimental working and living conditions varies depending on the type of job. Sleep disorders appear to represent a relevant health issue for offshore wind workers and arise independently from shift work and schedule.

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Strengths and limitations of this study

- Our work is one of the first to quantitatively assess the working and living conditions, physical demands, and subjective health of workers in the offshore wind industry.
- The study uncovers opportunities for interventions that could improve the health of offshore workers.
- The study design is cross-sectional, thus our findings, have to be interpreted with caution and do not fulfil all causality criteria (e.g. lack temporality).

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Introduction

Since the construction of the first offshore wind farm in Vindeby, Denmark, in 1991 [1], the total capacity of offshore wind power has been continuously increasing worldwide. Indeed, the global cumulative offshore power capacity has grown in the past ten years from less than 1,000 megawatts (MW) in 2007 to more than 14,000 MW in 2017 [2]. Accordingly, there has also been a continuous increase in the workforce involved in the construction and operation of such offshore wind installations. Although the majority of offshore wind farms are located in the waters off the coast of Europe, the industry is expanding rapidly to China, Vietnam, South Korea, Japan, India, and the US [3].

Analogous to the offshore oil and gas industry, the offshore wind workplace is predominantly characterised by its remoteness and hostile environment. Although so-called near-shore wind farms less than 3 nautical miles (5.5 km) from the coast do exist, the average distance of the European installations from their respective coasts is currently 23.5 nautical miles (43.5 km) [3]. Based on current plans for several more installations to be built at distances of 50 nautical miles or more from the coastline, this is projected to increase further. Typically, offshore wind farms consist of wind energy turbines, electric power transformation substations, and collector and converter substations, all spread over a variable water area. For example, in Germany, the area of active wind farms ranges from 1 km² to more than 50 km² (with an average of 30 km²) [2].

The remote locations and the extensiveness of the wind farms have important implications for the offshore workforce. While working on the installations, most employees have to live and sleep on platforms or ships for a period of several weeks, and operators and technicians have to be transported daily by boat or helicopter to

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the turbines and back during their shifts. Not only the technical staff, but also workers from other professions necessary for the operation of an offshore wind farm, such as site managers, caterers, and paramedics are subjected to the unique offshore working and living conditions.

In addition to the location aspect, the dimensions and technical characteristics of the installations themselves also pose specific demands on the workforce, particularly on the technical personnel. Currently, the turbines have an average height of 90 m and a rotor diameter of up to 150 m [4, 5]. As a result, working at extreme heights and in confined spaces, climbing, and carrying heavy equipment are unavoidable physical demands that employees are regularly confronted with [6].

Furthermore, the work schedule of offshore crews often requires regular periods of long absence from home, and day and night shifts of 12 hours are very common [7]. Irregular offshore schedules with varying lengths of stay do exist, however [8]. In general, shift work and long working hours have long been known to be associated with adverse health effects, particularly sleep disruptions [9].

In summary, work on offshore wind farms can be considered strenuous and challenging in terms of health considerations, requiring a high degree of physical and mental fitness [10]. It is comprised of a combination of features from other demanding jobs such as construction and operation of large-scale installations, seafaring, fire fighting, working overseas, etc.

The purpose of our study was to assess the working and living conditions of the employees in the offshore wind industry, as well as their subjective health status. We placed particular attention on sleep disorders and quality of sleep, and compared technical offshore staff with non-technical staff.

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Although there is considerable research on the working conditions, physical and psychological demands, and health issues of offshore workers from the oil and gas industry, there have been no systematic quantitative assessments of the working and living conditions of employees in the offshore wind energy branch. Although similar, there remain specific differences between the two industries, justifying a more in-depth investigation into this particular occupation and job environment.

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Methods

Study design and population

An online cross-sectional survey was carried out between September 2016 and January 2017 of persons working on offshore wind farms located in the German exclusive economic zone (EEZ) of the North and Baltic seas. By December 2016, there were 22 wind farms either already in operation or under construction in this area [2]. Although there are no exact data regarding the number of offshore workers involved in these installations, it has been estimated that up to 5,000 employees are directly or indirectly working on offshore wind farms within the German EEZ [11]; these represent our source population.

Recruitment

Participation was anonymous and voluntary. Participants were recruited by contacting offshore companies operating in the German EEZ via telephone and e-mail. We provided study information leaflets in both German and English via mail, e-mail, and personal communication to occupational physicians, health and safety managers, and human resources departments for distribution among their employees (e.g. via intranet, newsletters, e-mails, and word-of-mouth promotion). In addition, we promoted the study on relevant online platforms and forums. We also presented our study at the “Round-table Maritime Safety Partnership”, a regular meeting of key stakeholders organized by the German Offshore Wind Energy Foundation [12].

Questionnaire

The online questionnaire was designed with the platform SurveyMonkey®. It was

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accessible via electronic devices through its URL or QR-code, both provided in all written information materials (leaflets, e-mails, postings, etc.) used for recruitment. The questionnaire was available in German and English. The first page of the questionnaire provided information on the study aims and characteristics, as well as a required consent item to be filled out prior data collection. Access to the questionnaire was only granted after ticking off the sentence “I hereby confirm that I have read and understood the study information and data protection policy above. I agree to participate”. Termination of the survey was possible at any stage.

Sociodemographic variables

We collected data on gender, age, marital status, children, and nationality.

Job characteristics

We collected data on offshore experience (tenure in years), occupation type (e.g. technician, site manager), offshore work schedule (regular, irregular), work shifts, project phase of the wind park (operation, under construction), transportation arrangements, and offshore living conditions (location of accommodation and type of cabin).

Job demands

Participants were also asked to self-assess their level of exposure to a list of 18 physical demands and stressors from the work and living environment (modified from [13]) on a five-point Likert scale (“always” – “often” – “sometimes” – “rarely” – “never/hardly ever”). For comparison purposes, this variable was dichotomized

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merging the categories “always” and “often” on one side and “sometimes” to “never” on the other. Satisfaction with respect to different aspects of living (e.g. accommodation, canteen) and working (e.g. equipment, transfer) offshore was measured on a four-point Likert scale using self-constructed questions.

Subjective health

Self-rated general health was addressed on a five-point Likert scale (“very good” – “good” – “fair” – “bad” – “very bad”) as recommended by the WHO [14]. For comparison purposes, health status was then dichotomized by merging the categories “very good” and “good” on the one side and “fair”, “bad” and “very bad” on the other side, as is commonly done in health surveys [15].

Subjective health problems were assessed using the Subjective Health Complaints inventory (SHC) [16]. The SHC consists of 29 ordinary somatic and psychological health problems and complaints with severity being rated on a four-point scale (“not at all” – “a little” – “some” – “serious”) over a timeframe of 30 days. For ease of comparison, the variable can be dichotomized into “not at all” and “any” (the latter including all other answer categories) [16]. The single items can also be grouped into five sub-scales: musculoskeletal pain (maximum score = 24), gastrointestinal problems (maximum score = 21), pseudoneurology (maximum score = 21), allergy (maximum score = 15), and flu (maximum score = 6).

Following Riethmeister et al. [17], we asked participants whether or not they experience a “dip” (i.e. a state of severe mental or physical exhaustion) during longer offshore stays. Type and severity of dip, as well as the time point of occurrence, were recorded.

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Sleep quality was assessed according to the method used in the German Health Interview and Examination Survey for Adults (DEGS). Participants were first asked to report the incidence of sleep disorders (both sleep onset and sleep duration) over the past four weeks on a four-point scale ("not at all" – "less than once a week" – "1-2 times per week" – „3 or more times per week") [18]. We also dichotomized these variables, merging the categories "not at all" with "less than once a week" and "1 or 2 times per week" with "3 or more". Participants were then asked to rate their sleep quality during both offshore stays and onshore leave with Component 1 of the Pittsburgh Sleep Quality Index (PSQI). This is a four-point scale with the categories "very good" – "fairly good" – "poor" – "fairly poor" and a time horizon of four weeks [19]. For comparison, this variable was dichotomized merging "very good" with "fairly good" and „poor" with „fairly poor".

Using questions developed specifically for this study questions, we asked participants to report whether or not they had ever experienced seasickness during offshore stays and, if so, whether these incidents led to the inability to work. Another question referred to the issue of continuing to work despite feeling ill (presenteeism).

Statistics

In order to ensure our collective had sufficient exposure to the offshore environment, we restricted the sample to workers with regular offshore commitments or with a total of at least 28 days offshore during last year if working on an irregular schedule. Blank answers were treated as missing values and excluded from analysis. No imputation was done. Descriptive statistics are presented as means (standard deviation, SD) for continuous variables, and as frequencies and percentages for categorical variables. Bivariate associations were analysed with 2 x 2 contingency tables and Fisher's

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exact test. Mean differences across groups were tested either with a t-test or with the Mann-Whitney U test for variables with non-normal distribution. Two-tailed p-values were calculated. The statistical significance level was set at $p<0.05$. Statistical analyses were carried out using IBM® SPSS® Statistics (IBM Corp. released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.) and Epi Info™ 7.2.1.0 (Centers for Disease Control and Prevention, Atlanta, GA, USA).

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Results

Overall, 384 persons responded to the questionnaire (figure 1), although not all questions were always answered. Participant characteristics are shown in table 1. The majority of responders were male (92.6%) and German citizens (90.3%). The sample consisted mainly of experienced offshore workers with only 7.7% reporting less than one year of experience working in this environment. Regarding their specific occupations, management staff was the most represented group (44.0%) followed by technicians (operators, mechanics, and installers) (40.9%). Almost two thirds of the responders were working on wind farms that were already operational (64.3%), while 35.7% were working on installations in the construction phase.

A clear difference was observed between male and female offshore workers in terms of their family situations and their offshore occupations (table 1). Females, for example, were twice as likely to be single (36.0%) compared to males (14.3%). Furthermore, only 8.0% of the women had children under 18 years of age at home, compared to 43.1% of the men. Men were also more experienced with working away from home (78.6% vs. 42.1%). The majority of females (60.0%) were only occasionally deployed offshore, whereas most of the men (70.0%) had regular offshore commitments. Only 9.5% of the women were technicians/mechanics compared to 43.1% of the males. Consequently, less women had to be transferred by ship or helicopter to and from the installations during their offshore shifts (36.8% vs. 13.5%). All observations were statistically significant ($p<0.05$).

For the sake of comparability, we excluded female respondents from further analyses. The final sample, therefore, consisted of 268 male offshore workers (figure 1). As expected, in this subgroup, workers with a regular schedule of 14 days offshore work and 14 days onshore leave were overrepresented with 73.9% compared to all males

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(59.5%, see table 1). At the time of answering the questionnaire, 42.9% of the workers were actively offshore and 27.6% had finished their last offshore commitment less than 1 month beforehand (both were considered as “currently offshore” for comparisons below).

Job demands

Overall, the most frequently mentioned job demand was ’climbing’ with 63.8% of the respondents reporting to be always or frequently confronted with climbing and going up stairs during offshore work (additional Table A2). Noise was reported to be always or frequently present by 55.6% of the participants, followed by vibrations with 52.2%. Less frequent demands included working with reduced visibility, with 47.2% exposed either rarely or never, odours (46.0%), working with chemicals (41.3%), frequent changes between high and low temperatures (40.4%), and working overhead (40.2%).

Those working on installations under construction were more frequently exposed to most of the demands compared to those working on installations already in operation (see table 2a). The strongest associations were observed for working in a wet environment (RR 1,89; 95% CI 1,37 to 2,62) and having to lift and carry heavy loads (RR 1,46; 95% CI 1,10 to 1,94).

As shown in table 2b, technicians and mechanics were more often forced to work in non-ergonomic postures while offshore compared to the other occupations. Almost half of this group reported frequently working with a twisted or forward flexed upper body compared to only a quarter of the others (RR 2.21; 95% CI 1.53 to 3.18). Overhead work was reported less frequently, but was still twice as common among technicians and mechanics (24.8 vs. 10.9%, RR 2.29; 95% CI 1.28 to 4.09). A technical occupation was also associated with carrying or lifting heavy loads (RR

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1.76; 95% CI 1.29 to 2.40), having to generally work with heavy equipment (RR 1.68; 95% CI 1.25 to 2.17), or having to work with chemicals or hazardous substances (RR 1.68; 1.09 to 2.59) (table 2b). Other workers complained more about being restricted in their movements (31.8% vs. 28.0% among technicians) and having to work under reduced visibility (16.3% vs. 13.8%), although these differences were not statistically significant.

Work Satisfaction

Despite the presence and reported frequency of the above-mentioned factors, offshore workers were generally satisfied with their working and living environments (table 3). Satisfaction was highest with the safety equipment/precautionary measures available on the platforms, as well as the mode of transportation and transfer system used to access the installations. However, there was a considerable degree of dissatisfaction with work-related communication between offshore and onshore staff. Regarding accommodations and catering, the majority of workers were satisfied, although approximately one third were unsatisfied to highly unsatisfied with the leisure, sport, and sleep facilities, as well as with the lack of privacy. Workers lodging in double cabins were statistically significant more dissatisfied with both the lack of personal privacy and the sleeping facilities compared to those in single-occupancy cabins (48.5% vs. 15% and 40% vs. 16.3%, respectively). The highest degree of satisfaction was reported for the canteen. Regarding these aspects, there were no statistically significant differences observed among specific groups of occupations.

General health

None of the respondents reported having poor or very poor health, with 89% rating their health as either good or very good. There was no statistically significant difference between workers whose last offshore commitment was more than one

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month ago and those who were either still working offshore at the time of the survey or who had their last commitment finished within the previous month.

64.1% of the workers with offshore deployments of 14 days or longer reported experiencing a 'dip' (i.e. a state of mental and/or physical exhaustion) at some point during their stay. Half of these described experiencing both physical and mental exhaustion, whereas others reported either only mental (32.2%) or physical (17.5%) tiredness. Interestingly, younger workers reported experiencing such a dip more frequently than those 50 years of age or older (66.3% vs. 51.9%, p = 0.08). In terms of the timeline, for workers working 14 days or more offshore, the dips were most frequently reported on the 10th day (roughly 25%) (figure 2). There were no differences in the incidence of dip between technicians/mechanics and other jobs (figure 3). However, technicians reported physical exhaustion almost three times as often as those from other occupations (26.5% vs. 9.3%). Conversely, employees of other occupations reported experiencing mental dips twice as often as the technicians (42.7% vs. 20.6%).

Approximately one third (29.5%) of the workers had felt ill at some point during an offshore commitment but had not reported his health problem to the paramedic for fear of being sent home. This was true for all occupations.

Another third (29.7%) of the workers experienced seasickness during their offshore stay. Most often (88.3%), this was associated with transport to the installations by ship, although it also occurred at the offshore workplace (19.5%), as well as during offshore leisure time (13.0%).

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Subjective health complaints

The subjective health complaints item list (SHC) revealed tiredness to be the most frequent problem, with almost 75% of workers reporting at least some degree of tiredness within the past 30 days (table 3). Similarly, sleep disorders were reported by almost 60% of the participants, and neck and upper back pain were reported by over 50%. Sleep problems were statistically significant more prevalent for those workers who were offshore or who had recently been offshore (last commitment less than 30 days prior) at the time of the questionnaire (62% vs. 46%, RR 1.36; 95% CI 1.02 to 1.81). All other complaints did not differ between those workers who were offshore at the time and those who had been home/onshore for more than 30 days.

Technicians and mechanics showed a statistically significant higher risk of having shoulder pain (RR 1.44; 95% CI 1.02 to 2.05), neck pain (RR 1.43; 95% CI 1.10 to 1.85), back pain (RR 1.41; 95% CI 1.10 to 1.79), and arm pain (RR 2.31; 95% CI 1.36 to 3.92) than workers in other occupations. For all other complaints, no statistically significant differences were observed (additional table A3). Sub-scale scores of the SHC are shown in table 4: Technicians had a statistically significant higher score in the musculoskeletal sub-scale compared to the other occupational groups (mean difference 0.957, 95% CI 0.042 to 1.872). There were no differences in the other sub-scales for the occupational groups or the time point of answering the questionnaire.

Sleep

Sleep quality was reported to be worse during offshore commitments than during onshore stays by 47.9% of respondents, whereas 44.1% reported no location-dependent differences. Noise (49.3%) and air quality/air-conditioning (48.9%) were the most common reasons for interrupted sleep/poor sleep quality offshore. Limited

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privacy was also found to be a major reason for poor sleep quality (35.4%), as well as room temperature (21.3%). Table 5 shows the ratings for sleep quality, as well as the incidence of sleep troubles in the past four weeks. Trouble falling asleep on three or more nights per week occurred in 9.5% of the workers, while 16.5% had problems sleeping through the night on three or more occasions per week over the past month. Workers offshore at the time of survey reported trouble falling asleep more than once a week significantly more frequently (34.8%) compared with those whose last offshore commitment dated back 30 days or more (16.2%) (RR 2.15; 95% CI 1.20 to 3.84). Similarly, those workers also experienced more problems sleeping through the night at least one night a week (39.4% vs. 22.4%, RR 1.76; 95% CI 1.09 to 2.85). An association between type of sleeping accommodation and the incidence of sleep disorders could be observed, with problems occurring more frequently among workers in shared cabins. For example, only 23.8% of workers assigned to single cabins reported problems falling asleep more than once per week, compared to 38.6% of those in double-occupancy rooms (RR 1.63; 95% CI 1.10 to 2.41). A similar pattern emerged for problems sleeping through the night (28.9% vs. 44.8%, respectively, RR 1.55; 95% CI 1.02 to 2.19). The incidence of sleep problems was similar among those with accommodations onshore (i.e. island or mainland) and those sleeping offshore (i.e. on vessels or platforms). No effects of the type of shift work (rotating shift vs. day shift) were observed. The work schedule (regular vs. irregular commitments) was also not associated with the frequency of sleeping disorders.

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Discussion

Despite the growing workforce involved in the construction and operation of offshore wind farms, little is known about the working and living conditions or about the subjective health of these employees.

We found patterns of physical and ergonomic strain for offshore wind workers to be dependent on the phase of wind farm life-cycle (e.g. under construction or operational), as well as on the type of job performed (technicians/mechanics vs. other occupations). Differences in work-related factors among specific job groups have been previously described for offshore workers in the oil and gas industry [20]. As expected for workers in the construction and operation of large installations, the technicians in our sample were more often exposed to non-ergonomic postures during their tasks than other offshore workers, also having to deal more frequently with heavy loads or bulky equipment. Furthermore, musculoskeletal complaints were more frequently reported by technicians than non-technicians, suggesting an association between heavier ergonomic strain and complaints, a point which should be verified in future longitudinal research.

In general, the respondents of our survey were in better subjective health than the general population (89% in our sample vs. 73% among German males [21]). The prevalence of a good self-rated health status in our sample is comparable to that of academic professionals (92%) and substantially higher than that among manual labourers (76% to 82%) in the male German population [22]. This is not surprising, since the fitness requirements to work offshore are fairly stringent [23], thereby selecting for healthy workers. Interestingly, despite the high prevalence of good self-rated health, respondents in our sample reported health complaints in the SHC more frequently than those from samples of the general [16] and working populations [24].

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This difference lies mainly on the high prevalence of tiredness and musculoskeletal complaints among the offshore workers in our sample compared to the above-mentioned populations. This could be a reflection of the sometimes unavoidable requirements of performing tasks in awkward positions, heavy lifting, as well as the generally strenuous and physically demanding nature of the work, particularly among technicians. All these factors are known occupational causes of musculoskeletal disorders [25]. In addition, this difference between our group and the general population may be a result of the particular occupational stressors of the offshore environment, which also have been reported to be associated with the prevalence of such complaints among offshore workers [26].

In line with recent research, which has identified and described 'dips' as potentially harmful to offshore workers' health and safety [17], 64.1% of our sample also reported experiencing such a form of exhaustion, particularly around the 10th day of deployment. Our results indicate that the type of dips differ according to the type of job done. To best of our knowledge, the association between form of dip and job type has not previously been described and should be taken into account when designing preventive interventions to address this potentially dangerous phenomenon.

Our findings also reveal a high incidence of sleeping disorders among the respondents. As expected, workers who responded while offshore at the time of survey (or whose last offshore commitment was not longer than one month prior) reported more problems falling asleep than workers from the general population (35% of our sample had problems at least once per week compared to 23% of the most current German health survey [18]). This finding is consistent with previous research from the offshore oil and gas industry, which also showed a high prevalence of sleep disturbances [27]. In our group, sleep disorders and poor sleep quality were

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particularly associated with being or recently having been offshore and with shared accommodations. Surprisingly, no association between the type of shift schedule (day shifts only vs. rotating night and day shifts) was found. In contrast, in the offshore oil and gas industry, sleep disorders and sleep quality have been shown to be associated with working on rotating shifts [27], as well as with working overtime (i.e. 12 h or more), and with the offshore environment (cramped space, noise, and sea conditions) [28, 29]. Noise, vibrations, and cabin environment (e.g. humidity, temperature) have also been reported to be relevant sleep disturbers among seafarers [30]. In our study, noise, vibrations, and indoor air quality were also reported to be causes of poor sleep quality offshore compared to onshore. To our knowledge, however, the association between the type of sleep accommodation (e.g. single vs. double cabin) is a novel finding.

There is evidence that the difficulty in distinguishing between 'home' or leisure time and work while offshore, as well as the often-close relationships of the crew members, may promote sickness presenteeism (i.e. attending work when feeling ill) [31]. For the oil and gas offshore industry, it has been reported that up to 20% of workers choose not to report illness to the medic in order to avoid an onshore referral [32]. In our survey, one third of the workers reported not to have informed the paramedic about a health problem in order to avoid being sent onshore. Since presenteeism could have adverse consequences for safety at work and for health and well-being in the long term [33, 34], our results underline the need to consider this issue in organisations' HSE policies.

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Limitations

The main limitation of our study is its cross-sectional design, which prohibits an establishment of sound causal links in the associations observed. In addition, we cannot assess whether the respondents to our survey are representative of the population of workers at offshore wind farms. It has been estimated that approximately 5,000 persons are regularly or sporadically working on such installations in the German EEZ [11]. Based on this estimate, our study comprises roughly 7.5% of the total collective of offshore-wind workers in this area. A true response rate cannot be calculated, since the web survey was also promoted via online platforms/forums. Although there are no reliable data on the demographic characteristics of this group of German offshore wind industry workers, according to expert opinions (occupational physicians, health and safety managers), the gender distribution of the respondents to our survey does indeed correspond to the actual male to female ratio of the workforce. Since we excluded female employees in the detailed analyses of the health and working and living conditions of the study population, our results are only applicable to the male subgroup.

Furthermore, because the offshore wind energy industry is relatively young, there is a need for additional longitudinal research on the long-term effects of offshore work on the health and well-being of its employees.

Implications for clinicians and policy makers

Our findings have implications for occupational physicians and health safety managers taking care of offshore workers and. These results highlight the importance of having detailed knowledge of the concrete job tasks and workplace and living conditions of employees when assessing fitness to work and/or occupational risks. Indeed, jobs in the offshore wind industry differ substantially in terms of their health

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risks and demands, and these differences must be considered in order to provide adequate and individually-tailored occupational medical advice. Sleeping disorders are common among offshore workers, particularly during offshore commitments, and thus represent an important issue for health-care personnel working with offshore employees. Our results indicate that sleep problems are associated with the living conditions offshore, particularly with the type of accommodation and the presence of environmental stressors such as noise, vibrations, and artificial ventilation. Such factors should therefore be considered in the planning and construction of future offshore housing facilities and service vessels, in order to minimize their detrimental influence on the sleep quality of offshore workers. Policy makers and regulators could help achieve this goal of building better facilities by enhancing or modifying the requirements and standards for the licensing of new offshore installations and housing facilities, thereby overcoming the current shortcomings in the accommodation of offshore workers.

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Conclusions

Workers in the offshore wind industry comprise a heterogeneous group, including a wide variety of occupations, job tasks, and work schedules, ranging from regular offshore commitments every two weeks with 12-hour shifts over 14 days, to sporadic deployments of only a few days. The degree of exposure to detrimental working and living conditions, therefore, varies considerably depending on the type of job done offshore. In also depends on whether the installations are in construction or fully operational/in service. Despite this, some complaints, such as sleep disorders, appear to be a relevant health problem for all offshore workers, independent of the above-mentioned factors. With the insights gained in our study, we provide evidence useful for the planning of interventions aiming to improve the working and living conditions of employees while offshore.

Authors' contributions

AMP and SM conceived the study and led the application for funding. MVG and JM designed the survey with input from SM and AMP. MVG ran the statistical analysis and wrote the first draft. All authors (MVG, JM, SM, VH, AMP) contributed to interpret the data, provided input on the first draft and revised the manuscript.

Funding

Our work was supported by the German Federal Ministry of Education and Research (grant number: 01FA15029).

Competing interests

MVG, JM, SM, VH, and AMP declare that they have no competing interests.

Ethics

Ethics Review Committee of the Hamburg Medical Association

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Acknowledgements

We thank all offshore workers who responded the survey. We are also indebted to all company physicians, health and safety managers and all other staff who contributed to widespread the survey.

We thank Rosalie McDonough for reviewing the paper.

Data Sharing Statement

No additional data are available

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Reference

1. Nixon N. Timeline: The history of wind power. The Guardian, October 17th 2008. https://www.theguardian.com/environment/2008/oct/17/wind-power-renewable-energy (accessed 30 Sep 2017).
2. Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). Wind Monitor – Development in Germany. Kassel: IWES, 2016 http://windmonitor.iwes.fraunhofer.de/windmonitor_en/4_Offshore/1_zubau/2_entwicklung_in_deutschland/index.html (accessed 30 Sep 2017).
3. Global Wind Energy Council (GWEC). Global Wind Report 2016 – Annual market update. Brussels: GWEC, 2016 http://files.gwec.net/register?file=/files/GWR2016.pdf (accessed 30 Sep 2017).
4. Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). Wind Monitor – Turbines Size. Kassel: IWES, 2016 http://windmonitor.iwes.fraunhofer.de/windmonitor_en/4_Offshore/2_technik/3_Anlagengroesse/ (accessed 30 Sep 2017).
5. Stiftung Offshore Windenergie. Offshore Wind Energie – sauberer Strom aus dem Meer [Offshore wind energy - clean energy from the sea]. Varel: Stiftung Offshore Windenergie, 2016 http://www.offshore-stiftung.de/offshore-windenergie (accessed 30 Sep 2017).
6. Velasco Garrido M, Mette J, Mache S, Harth V, Preisser AM. Belastungen und Gefährdungen der Beschäftigten in der Offshore-Windindustrie [Demands and hazards of working in the offshore wind power industry]. Arbeitsmed Sozialmed Umweltmed 2017; 52(2): 134-137.
7. Parkes KR. Offshore working time in relation to performance, health and safety. A review of current practice and evidence. Norwich: Health and Safety Executive, 2010. Research Report RR772.
8. Mette J, Velasco Garrido M, Preisser AM, Harth V, Mache S. 'It's Still a Great Adventure' – Exploring Offshore Employees' Working Conditions in a Qualitative Study. Manuscript submitted for publication.
9. Akerstedt T. Shift work and disturbed sleep/wakefulness. Occup Med (Lond) 2003; 53: 89-94,

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10. Preisser AM, McDonough R, Harth V: Fitness to work: a comparison of European guidelines in the offshore wind industry. Int Maritime Health 2016; 67: 227-234
11. Federal Ministry for economic affairs and energy. Offshore wind energy – an overview of activities in Germany. Berlin: FMEAE, 2015 https://www.bmwi.de/Redaktion/EN/Publikationen/offshore-wind-energy.pdf?__blob=publicationFile&v=3 (accessed 30 Sep 2017).
12. Stiftung Offshore Windenergie. Vernetzung der maritimen Wirtschaft mit der Branche der Offshore-Windenergie 2 [Networking between maritime industry and offshore wind energy branch]. Varel: Stiftung Offshore Windenergie, 2017 https://www.offshore-stiftung.de/Vernetzung (accessed 30 Sep 2017).
13. Bjerkan AM. Work, health and safety culture/climate. A study of employees in the Norwegian oil and gas industry. Oslo: Centre for Technology, Innovation and Culture, University of Oslo, 2010.
14. de Bruin A, Picavet HSJ, Nossikov A (eds.). Health interview surveys: towards international harmonization of methods and instruments. Geneve: World Health Organisation, 1996.
15. Subramanian SV, Huijts T, Avendano M. Self-reported health assessments in the 2002 World Health Survey: how do they correlate with education? Bull World Health Organ 2010; 88(2): 131–138.
16. Eriksen HR, Ihlebaek C, Ursin H. A scoring system for subjective health complaints (SHC). Scand J Public Health 1999; 1: 63-72.
17. Riethmeister V, Brouwer S, van der Klink J, Bültmann U. Work, eat and sleep: towards a healthy ageing at work program offshore. BMC Public Health 2016; 16:134,
18. Schlack R, Hapke U, Maske U, Busch MA, Cohrs S. Frequency and distribution of sleep problems and insomnia in the adult population in Germany. Results of the German Health Interview and Examination Survey for Adults (DEGS1). Bundesgesundheitsbl 2013; 56:740-748.
19. Buysse DJ, Reynolds ICF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989; 28: 193-123.
20. Bjerkan AM. Work and health: a comparison between Norwegian onshore and offshore employees. Work 2011; 40: 125-142.

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21. Robert Koch Institut. Subjektive Gesundheit. Faktenblatt zu GEDA 2012: ergebnisse der Studie „Gesundheit in Deutschland aktuell 2012“. [Subjective healt. GEDA fact-sheet: Results of the study „Health in Germany 2012”]. Berlin: Robert Koch Institut, 2014.
22. Burr H, Kersten N, Kroll L, Hasselhorn HM. Selbstberichteter allgemeiner Gesundheitszustand nach Beruf und Alter in der Erwerbsbevölkerung [Self-rated general health by occupation and age in the working population in Germany]. Bundesgesundheitsbl 2013; 56: 349-358.
23. Preisser AM, Decker U, Faesecke KP, et al. Arbeitsmedizinische Eignungsuntersuchung für Arbeitnehmer auf Offshore-Windenergieanlagen und anderen Offshore-Installationen [Fitness-to-work for workers in offshore wind energy and other offshore installations. Munich: Deutsche Gesellschaft für Arbeitsmedizin und Umweltmedizin, 2015.
24. Indregard A-MR, Ihlbaek CM, Eriksen HR. Modern health worries, subjective health complaints, health care utilization, and sick leave in the Norwegian working population. Int J Behav Med 2013; 20: 371-377.
25. da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am J Ind Med. 2010; 53: 285–323.
26. Chen WQ, Yu ITS, Wong TW. Impact of occupational stress and other psychosocial factors on musculoskeletal pain among Chinese offshore oil installation workers. Occup Environ Med 2005; 62: 251-256.
27. Fossum IN, Bjorvatn B, Waage S, Pallesen S. Effects of shift and night work in the offshore petroleum industry: a systematic review. Industrial Health 2013; 51: 530-544.
28. Parkes KR. Sleep patterns of offshore day-workers in relation to overtime work and age. Appl Ergon 2015; 48: 232-239.
29. Parkes KR. Work environment, overtime and sleep among offshore personnel. Accid Anal Prev 2017; 99: 383-388.
30. Hansen JH, Holmen IM. Sleep disturbances among offshore fleet workers. A questionnaire-based survey. Int Marit Health 2011; 62, 2: 123–130.
31. Krohne K, Magnussen LH. Go to work or report sick? A focus group study on decisions of sickness presence among offshore catering section workers BMC Res Notes 2011; 4: 70.

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32. Mearns K, Hope L. Health and well-being in the offshore environment: the management of personal health. Merseyside: Health and Safety Executive, 2005.

33. Sanderson K, Cocker F. Presenteeism - Implications and health risks. Aust Fam Physician 2013; 42: 172-175.

34. Skagen K, Collins AM. The consequences of sickness presenteeism on health and wellbeing over time: A systematic review. Soc Sci Med 2016; 161: 169-77.

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Table 1. Demographic and occupational characteristics of all participants and subgroups (*only male with more than 28 days offshore)

Variable	All (n=384) n	All (n=384) %	Male (n=351) n	Male (n=351) %	Female (n=28) n	Female (n=28) %	Male >28d* (n=268) n	Male >28d* (n=268) %
Age (n=381)								
20-34 years	163	42.8	147	41.9	15	55.6	116	43.4
35-49 years	167	43.8	158	45.0	8	29.6	122	45.5
⩾ 50 years	51	13.4	46	13.1	4	14.8	30	11.2
Nationality (n= 370)								
German	334	90.3	307	89.8	23	95.8	234	89.3
other	36	9.7	35	10.2	1	4.2	28	10.7
Relationship status (n=379)								
single	60	15.8	50	14.3	9	36.0	41	15.4
in a relationship	319	84.2	300	85.7	16	64.0	226	84.6
Children under 18 yr. living at home (n=379)								
yes	154	40.6	151	43.1	2	8.0	121	45.1
Previous experience working far from home (n=348)								
yes	259	74.4	248	78.6	8	42.1	204	77.9
Offshore experience (n=362)								
< 1year	28	7.7	26	7.7	2	9.5	14	5.2
1-3 years	115	31.8	102	30.3	11	52.4	81	30.3
> 3 years	219	60.5	209	62.0	8	38.1	172	64.4
Occupation (n=359)								
management onshore (back office)	60	16.7	52	15.6	7	33.3	15	5.6
management offshore / supervisor	98	27.3	90	26.9	7	33.3	83	31.0
technician / mechanic	147	40.9	144	43.1	2	9.5	131	48.9
other	54	15.0	48	14.4	5	23.8	39	14.5
Work schedule (n=357)								
regular, 14 / 14	208	58.3	198	59.5	8	40.0	198	73.9
regular, other	35	9.8	35	10.5	-	-	35	13.0
occasional commitments	114	31.9	100	30.0	12	60.0	35	13.0
Work shifts (n=349)								
day shifts only	196	56.2	180	55.2	13	68.4	130	49.4
night shifts only	1	0.2	1	0.3	-	-	1	0.4
rotating shifts (day / night shifts)	152	43.6	145	44.5	6	31.6	132	50.2
Project phase of wind farm (n=359)								
under construction	128	35.7	117	35.1	7	33.3	94	35.2
in operation	231	64.3	216	64.9	14	66.7	173	64.8
Accommodation (n=348)								
offshore platform	160	46.0	151	46.3	7	38.9	116	44.1
offshore hotel ship	83	23.9	75	23.0	7	38.9	67	25.5
offshore construction ship	50	14.4	49	15.0	1	5.6	44	16.7
island / mainland hotel/flat	55	15.8	51	15.6	3	16.7	36	13.7
Type of room (n=344)								
single cabin	221	64.2	204	63.4	14	77.8	165	63.0
double cabin	123	35.8	118	36.6	4	22.2	97	37.0
Transfer from accommodation to workplace (n=349)								
ship	98	28.1	91	27.9	6	31.6	76	28.9
helicopter	106	30.4	100	30.7	4	21.1	74	28.1
both	94	26.9	91	27.9	2	10.5	78	29.7
none (e.g. living and working on platform)	51	14.6	44	13.5	7	36.8	13	13.3

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Table 2a. Physical demands and strains according to the phase of the wind farm.

Factor	Phase of the wind farm: under construction n*	%	in operation n*	%	RR	95% CI
Noise (n=251)	57	64.0	82	50.6	**1.27**	**1.02 to 1.57**
Vibrations/oscillation (n=254)	53	58.9	80	48.8	1.21	0.96 to 1.52
Humidity/moisture (n=253)	46	51.1	44	27.0	**1.89**	**1.37 to 2.62**
Cold (n=253)	32	35.6	44	27.0	1.32	0.91 to 1.92
Heat (n=254)	24	26.7	34	20.9	1.28	0.81 to 2.02
Frequent changes between heat and cold (n=251)	21	23.6	35	21.6	1.09	0.68 to 1.76
Odours (n=251)	15	16.9	33	20.4	0.83	0.48 to 1.44
Contact with chemicals or hazardous substances (n=251)	19	21.3	46	28.4	0.75	0.47 to 1.20
Lifting/carrying heavy loads (n=252)	47	52.8	59	36.2	**1.46**	**1.10 to 1.94**
Transport of aids (e. g. PPE, tools) over long distances (n=253)	45	51.1	75	45.7	1.12	0.86 to 1.46
Working with twisted upper body/forward flexion of the spine (n=253)	40	44.9	51	31.1	**1.45**	**1.05 to 2.00**
Working with unsupported raised arms (overhead work) (n=253)	20	22.5	25	15.2	1.47	0.87 to 2.50
Reduced visibility (n=251)	17	19.3	21	12.9	1.50	0.84 to 2.69
Closed/cramped quarters (n=252)	41	46.1	53	32.5	**1.42**	**1.03 to 1.94**
Climbing (n=253)	66	74.2	95	57.9	**1.28**	**1.07 to 1.53**
Poor air quality/air conditioning (n=252)	28	31.8	70	42.7	0.75	0.52 to 1.06
Restricted movement (n=253)	28	31.5	48	29.3	1.08	0.73 to 1.59
Unpredictable waiting times (e.g. during "weather days") (n=253)	43	48.3	55	33.5	**1.44**	**1.06 to 1.95**

Bold typeface indicates significance at p<0.05
*n indicates the number of workers reporting exposure “always” or “often”

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Table 2b. Physical demands and strains by type of occupation.

Factor	Type of occupation: technicians/mechanics n†	%	other* n†	%	RR	95% CI
Noise (n=252)	77	61.6	63	49.6	1.24	0.99 to 1.55
Vibrations/oscillation (n=255)	75	59.5	58	45.0	**1.32**	**1.04 to 1.68**
Humidity/moisture (n=254)	52	41.3	38	29.7	1.39	0.99 to 1.95
Cold (n=254)	42	33.3	34	26.6	1.26	0.86 to 1.83
Heat (n=254)	38	30.4	20	15.5	**1.96**	**1.21 to 3.18**
Frequent changes between heat and cold (n=252)	29	23.4	27	21.1	1,11	0.70 to 1.76
Odours (n=252)	24	19.5	24	18.6	1.05	0.63 to 1.75
Contact with chemicals or hazardous substances (n=252)	40	32.5	25	19.4	**1.68**	**1.09 to2.59**
Lifting/carrying heavy loads (n=253)	67	53.6	39	30.5	**1.76**	**1.29 to 2.40**
Transport of aids (e. g. PPE, tools) over long distances (n=253)	74	59.2	46	35.9	**1.65**	**1.25 to 2.17**
Working with twisted upper body/forward flexion of the spine (n=254)	62	49.6	29	22.5	**2.21**	**1.53 to 3.18**
Working with unsupported raised arms (overhead work) (n=254)	31	24.8	14	10.9	**2.29**	**1.28 to 4.09**
Reduced visibility (n=252)	17	13.8	21	16.3	0.85	0.47 to 1.53
Closed / cramped quarters (n=253)	54	43.2	40	31.3	1.38	1.00 to 1.92
Climbing (n=254)	95	76.0	67	51.9	**1.46**	**1.21 to 1.77**
Poor air quality/air conditioning (n=253)	52	41.6	46	35.9	1.16	0.85 to 1.58
Restricted movement (n=254)	35	28.0	41	31.8	0.88	0.60 to 1.29
Unpredictable waiting times (e.g. during "weather days") (n=254)	50	40.0	48	37.2	1.08	0.79 to 1.47

Bold typeface indicates significance at $p<0.05$
*other: site manager, back-office manager, supervisor, platform crew, paramedics, ship's crew, platform crew, research staff, quality manager, HSE staff
†n indicates the number of workers reporting exposure "always" or "often"

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Table 3. Subjective health complaints (SHC)

SHC		Not at all		A little		Some		Serious	
	N	n	%	n	%	n	%	n	%
Flu subscale									
cold / flu	236	153	64.8	54	22.9	22	9.3	7	3.0
Coughing	235	160	68.1	49	20.9	22	9.4	4	1.7
Musculoskeletal pain subscale									
shoulder pain	234	151	64.5	54	23.1	25	10.7	4	1.7
neck pain	236	117	49.6	68	28.8	43	18.2	8	3.4
upper back pain	237	109	46.0	81	34.2	38	16.0	9	3.8
arm pain	235	183	77.9	34	14.5	15	6.4	3	1.3
Headache	232	123	53.0	79	34.1	29	12.5	1	0.4
low back pain	233	139	59.7	68	29.2	22	9.4	4	1.7
leg pain during physical activity	236	181	76.7	39	16.5	13	5.5	3	1.3
Migraine	233	211	90.6	14	6.0	8	3.4	0	0
Pseudoneurology subscale									
Anxiety	236	185	78.4	35	14.8	16	6.8	0	0
sadness/depression	235	168	71.5	49	20.9	15	6.4	0	0
sleep problems	237	101	42.6	90	38.0	39	16.5	7	3.0
Tiredness	237	59	24.9	107	45.1	59	24.9	12	5.1
extra heartbeats	237	209	88.2	23	9.7	5	2.1	0	0
heat flushes	236	207	87.7	24	10.2	5	2.1	0	0
Dizziness	235	213	90.6	21	8.9	1	0.4	0	0
Gastrointestinal subscale									
stomach discomfort	239	199	83.3	31	13.0	9	3.8	0	0
Heartburn	238	177	74.4	42	17.6	13	5.5	6	2.5
ulcer/non-ulcer dyspepsia	239	199	83.3	33	13.8	7	2.9	0	0
stomach pain	235	211	89.8	20	8.5	4	1.7	0	0
gas discomfort	239	124	51.9	74	31.0	33	13.8	8	3.3
Diarrhoea	239	190	79.5	36	15.1	13	5.4	0	0
Obstipation	236	218	92.4	13	5.5	5	2.1	0	0
Allergy subscale									
Asthma	237	231	97.5	4	1.7	2	0.8	0	0
breathing difficulties	237	227	95.8	7	3.0	2	0.8	1	0.4
Allergies	237	213	89.9	15	6.3	8	3.4	1	0.4
Eczema	237	220	92.8	11	4.6	6	2.5	0	0
chest pain	236	225	95.3	10	4.2	1	0.4	0	0

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Table 4. Subjective health complaints – subscales by occupation

SHC subscale	All			Type of occupation: technicians			Type of occupation: other*			mean difference	95% CI of difference		p†
	n	mean	SD	n	mean	SD	n	mean	SD				
Flu	234	0.927	1.377	115	0.983	1.331	119	0.874	1.424	0.109	-0.247	0.464	0.254
Musculoskeletal pain	225	3.800	3.508	109	4.294	3.575	116	3.336	3.393	**0.957**	**0.042**	**1.872**	**0.010**
Pseudoneurology	233	2.906	2.600	115	2.713	2.342	118	3.093	2.825	-0.380	-1.051	0.291	0.517
Gastrointestinal	233	1.893	2.351	117	2.111	2.569	116	1.672	2.097	0.439	-0.167	1.044	0.182
Allergy	234	0.386	1.064	118	0.356	1.151	118	0.874	1.424	-0.593	-0.333	0.214	0.257

*other: site manager, back-office manager, supervisor, platform crew, paramedics, ship's crew, platform crew, research staff, quality manager, HSE staff
†Mann-Withney U test

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Table 5. Sleep quality

Item	All		Time point					Shift					Type of sleep cabin				
			Currently		> 1 Mo.			Day shift		Rotating shift			Double		Single		
	n	%	n	%	n	%	p	n	%	n	%	p	n	%	n	%	p
PSQI																	
Very bad	4	1.7	3	1.8	1	1.5		2	1.7	2	1.7		1	1.1	3	2.1	
Poor	45	19.1	37	22.0	8	11.8		19	16.2	26	22.0		21	23.6	24	16.4	
Fairly good	158	66.9	110	65.5	48	70.6		84	71.8	73	61.9		55	61.8	103	70.5	
Very good	29	12.3	18	10.7	11	16.2	0.225	12	10.3	17	14.4	0.437	12	13.1	16	11.0	0.443
Sleep disorders – falling asleep																	
Not at all	86	37.1	53	32.3	33	48.5		41	35.7	45	38.8		28	31.8	57	39.9	
< 1 / week	78	33.6	54	32.9	24	35.3		42	36.5	36	31.0		26	29.5	52	36.4	
1-2 / week	46	19.8	37	22.6	9	13.2		24	20.9	21	18.1		21	23.9	25	17.5	
≥3 / week	22	9.5	29	12.2	2	2.9	**0.019**	8	7.0	14	12.1	0.479	13	14.8	9	6.3	0.074
Sleep disorders – sleeping through																	
Not at all	81	34.2	51	30.0	30	44.8		39	32.8	42	35.9		20	23.0	60	40.3	
< 1 / week	74	31.2	52	30.6	22	32.8		38	31.9	35	29.9		28	32.2	46	30.9	
1-2 / week	43	18.1	35	20.6	8	11.9		27	22.7	16	13.7		18	20.7	25	16.8	
≥3 / week	39	16.5	32	18.8	7	10.4	0.066	15	12.6	24	20.5	0.164	21	29.1	18	12.1	**0.017**

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Figures

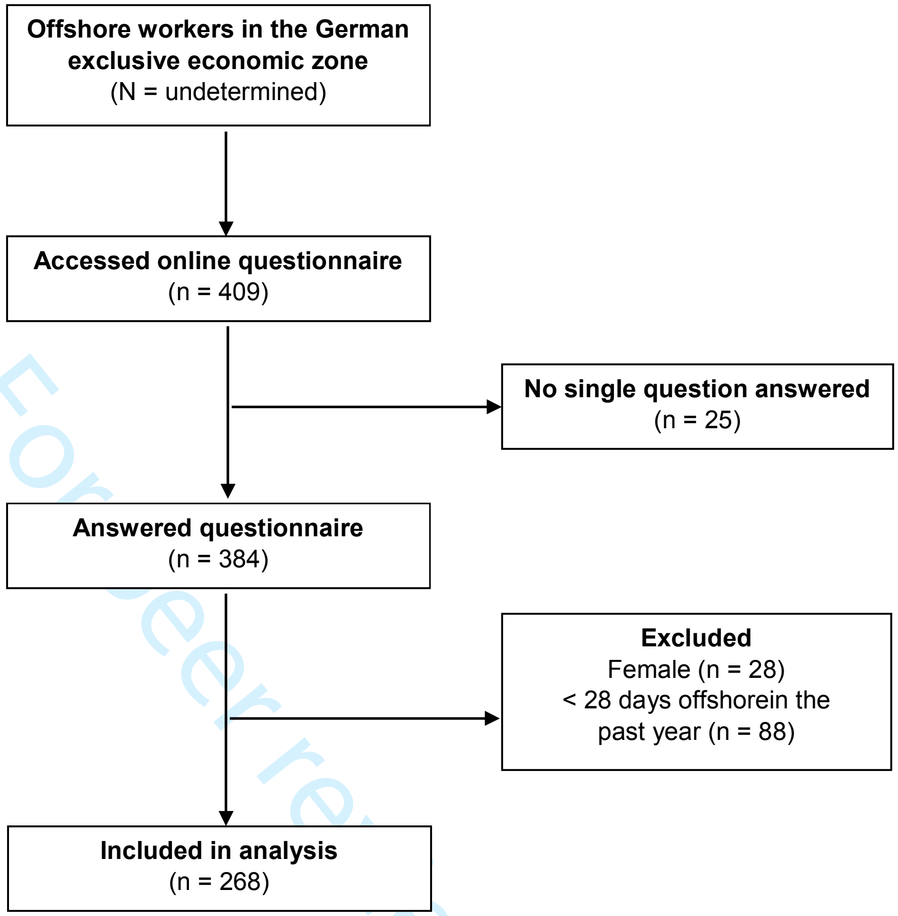

Figure 1. Study flow

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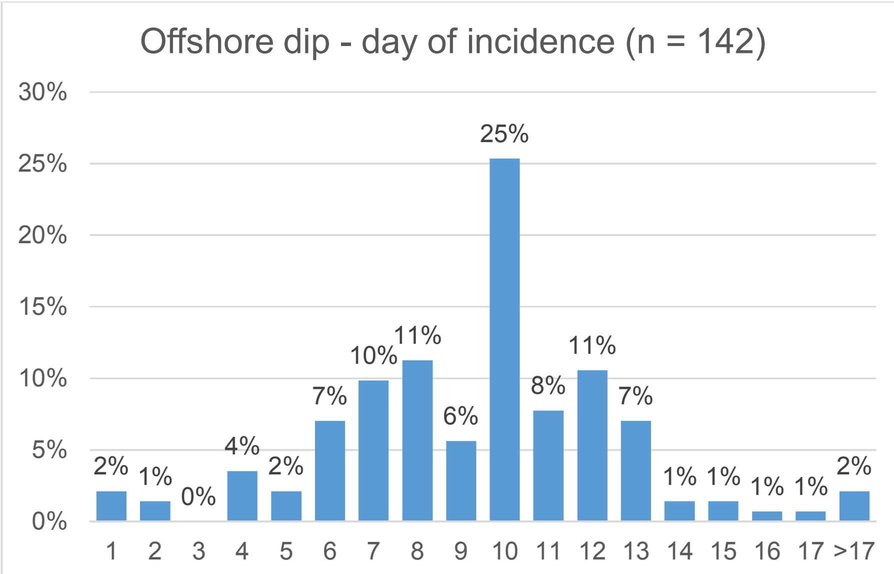

Figure 2. Day of incidence of offshore dip (n = 142).

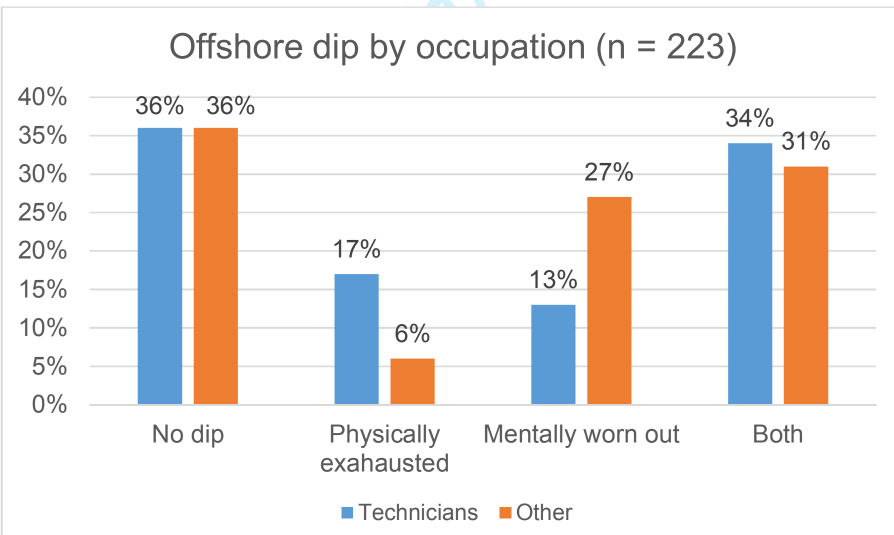

Figure 3. Type of dip according to occupation

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Additional Tables

Table A1. Job demands.

	Always		Often		Sometimes		Rarely		Never / hardly ever	
	n	%	n	%	n	%	n	%	n	%
Noise (n=252)	35	13.9	105	41.7	87	34.5	21	8.3	4	1.6
Vibrations/oscillation (n=255)	39	15.3	94	36.9	69	27.1	37	14.5	16	6.3
Humidity/moisture (n=254)	6	2.4	84	33.1	119	46.9	36	14.2	9	3.5
Cold (n=254)	3	1.2	73	28.7	145	57.1	25	9.8	8	3.1
Heat (n=254)	3	1.2	55	21.7	153	60.2	37	14.6	6	2.4
Frequent changes between heat and cold (n=252)	8	3.2	48	19.0	94	37.3	81	32.1	21	8.3
Odours (n=252)	7	2.8	41	16.3	88	34.9	90	35.7	26	10.3
Contact with chemicals or hazardous substances (n=252)	8	3.2	57	22.6	83	32.9	76	30.2	28	11.1
Lifting / carrying heavy loads (n=253)	16	6.3	90	35.6	86	34.0	51	20.2	17	6.7
Transport of aids (e. g. PPE, tools) over long distances (n=253)	44	17.4	76	30.0	73	28.9	43	17.0	17	6.7
Working with twisted upper body/forward flexion of the spine (n=254)	9	3.4	82	32.3	89	35.0	51	20.1	23	9.1
Working with unsupported raised arms (overhead work) (n=254)	1	0.4	44	17.3	107	42.1	70	27.6	32	12.6
Reduced visibility (n=252)	0	0.0	38	15.1	95	37.7	83	32.9	36	14.3
Closed/cramped quarters (n=253)	14	5.5	80	31.6	95	37.5	47	18.6	17	6.7
Climbing (n=254)	54	21.3	108	42.5	52	20.5	26	10.2	14	5.5
Poor air quality / air conditioning (n=253)	30	11.9	68	25.4	72	28.5	66	26.1	17	6.7
Restricted movement (n=254)	11	4.3	65	25.6	86	33.9	60	23.6	32	12.6
Unpredictable waiting times (e.g. during "weather days") (n=254)	6	2.4	92	36.2	111	43.7	39	15.4	6	2.4

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Table A2. Satisfaction with aspects of the work and living conditions offshore.

		Highly unsatisfied		Unsatisfied		Satisfied		Very satisfied	
	N	n	%	n	%	n	%	n	%
Cabin/sleeping accommodation	**244**	16	6.6	46	18.9	142	58.2	40	16.4
Canteen/lunchroom	**238**	13	5.5	23	9.7	138	58.0	37	14.5
Recreational spaces	**242**	16	6.6	69	28.5	137	56.6	20	8.3
Sport / fitness facilities	**237**	27	11.4	55	23.2	127	53.6	28	11.8
Privacy	**242**	21	8.7	45	18.6	147	60.7	29	12.0
Safety and protective equipment	**242**	2	0.8	18	7.4	125	51.7	97	40.1
Transfer between ship / helicopter and workplace	**237**	5	2.1	13	5.5	139	58.6	80	33.8
Work related offshore-onshore communication	**242**	28	11.6	70	28.9	125	51.7	19	7.9

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Table A3. Subjective health complaints by occupation and by time point of answering the questionnaire

	by occupation						by time point answering					
	technicians		Other*				currently		> 1 mo. ago			
SHC	**n†**	**%**	**n†**	**%**	**RR**	**95% CI**	**n†**	**%**	**n†**	**%**	**RR**	**95% CI**
Flu subscale												
cold/flu	46	39.3	37	31.1	1.26	0.89 to 1.79	58	34.5	25	36.8	0.94	0.65 to 1.37
coughing	39	33.9	36	30.0	1.13	0.79 to 1.64	53	31.5	22	32.8	0.96	0.64 to 1.45
Musculoskeletal pain subscale												
shoulder pain	48	42.1	35	29.2	1.44	1.02 to 2.05	59	35.1	24	36.4	0.97	0.66 to 1.41
neck pain	69	59.5	50	41.7	1.43	1.10 to 1.85	85	50.0	34	51.5	0.97	0.73 to 1.28
upper back pain	74	63.2	54	45.0	1.41	1.10 to 1.79	87	50.9	41	62.1	0.82	0.65 to 1.04
arm pain	36	31.0	16	13.4	2.31	1.36 to 3.92	41	24.3	11	16.7	1.46	0.80 to 2.66
headache	49	43.8	60	50.0	0.88	0.66 to 1.15	77	46.4	32	48.5	0.96	0.71 to 1.29
low back pain	51	44.3	43	36.4	1.22	0.89 to 1.67	65	39.2	29	43.3	0.91	0.65 to 1.26
leg pain during physical activity	33	28.4	22	18.3	1.55	0.97 to 2.50	42	24.9	13	19.4	1.28	0.74 to 2.23
migraine	14	12.3	8	6.7	1.83	0.80 to 4.19	17	10.2	5	7.6	1.34	0.52 to 3.49
Pseudoneurology subscale												
anxiety	20	17.1	31	26.1	0.66	0.40 to 1.08	35	20.8	16	23.5	0.89	0.53 to 1.49
sadness/depression	30	25.6	37	31.4	0.82	0.54 to 1.23	43	25.7	24	35.3	0.73	0.48 to 1.10
sleep problems	69	58.5	67	56.3	1.04	0.83 to 1.29	105	62.1	31	45.6	1.36	1.03 to 1.81
tiredness	92	78.0	86	72.3	1.08	0.93 to 1.25	125	74.0	53	77.9	0.95	0.81 to 1.11
extra heartbeats	9	7.6	19	16.0	0.48	0.23 to 1.01	19	11.2	9	13.2	0.85	0.41 to1.78
heat flushes	11	9.4	18	15.1	0.62	0.31 to 1.26	21	12.5	8	11.8	1.06	0.50 to 2.28
dizziness	13	11.1	9	7.6	1.46	0.65 to 3.28	15	8.9	7	10.4	0.86	0.37 to 2.00
Gastrointestinal subscale												
stomach discomfort	21	17.6	19	15.8	1.12	0.63 to 1.96	33	19.3	7	10.3	1.88	0.87 to 4.03
heartburn	35	29.7	26	21.7	1.37	0.88 to 2.12	44	25.9	17	25.0	1.04	0.64 to 1.68
ulcer / non-ulcer dyspepsia	23	19.3	17	14.1	1.36	0.77 to 2.42	28	16.4	12	17.6	0.93	0.50 to 1.72
stomach pain	12	10.3	12	10.2	1.01	0.47 to 2.15	17	10.2	7	10.3	0.99	0.43 to 2.28
gas discomfort	63	52.9	52	43.3	1.22	0.94 to 1.59	80	46.8	35	51.5	0.91	0.69 to 1.20
diarrhoea	27	22.7	22	18.3	1.24	0.75 to 2.05	34	19.9	15	22.1	0.90	0.53 to 1.55
obstipation	10	8.5	8	6.8	1.25	0.51 to 3.06	15	8.9	3	4.5	1.98	0.59 to 6.63
Allergy subscale												
asthma	3	2.5	3	2.5	1.01	0.21 to 4.90	3	1.8	3	4.5	0.39	0.08 to 1.90
breathing difficulties	6	5.1	4	3.4	1.51	0.44 to 5.22	7	4.1	3	4.5	0.92	0.25 to 3.45
allergies	9	7.6	15	12.6	0.61	0.28 to 1.33	14	8.2	10	14.9	0.55	0.26 to 1.18
eczema	7	5.9	10	8.4	0.71	0.28 to 1.79	12	7.1	5	7.5	0.95	0.35 to 2.58
chest pain	7	5.9	4	3.4	1.75	0.53 to 5.82	8	4.7	3	4.5	1.06	0.29 to 3.87

*other: site manager, back-office manager, supervisor, platform crew, paramedics, ship's crew, platform crew, research staff, quality manager, HSE staff
†n indicates the number of workers reporting having the complaint

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	1,4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-8
Bias	9	Describe any efforts to address potential sources of bias	*8,9*
Study size	10	Explain how the study size was arrived at	9,10, Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n.a.
		(*e*) Describe any sensitivity analyses	n.a.
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9,10, Figure 1
		(b) Give reasons for non-participation at each stage	9,10, Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	All tables and figures
Outcome data	15*	Report numbers of outcome events or summary measures	10-14, all tables
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-14, all tables
		(*b*) Report category boundaries when continuous variables were categorized	n.a.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n.a.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n.a.
Discussion			
Key results	18	Summarise key results with reference to study objectives	15-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-17, 18
Generalisability	21	Discuss the generalisability (external validity) of the study results	18-19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Physical strains of offshore wind farm workers – a cross-sectional study.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-020157.R1
Article Type:	Research
Date Submitted by the Author:	29-Dec-2017
Complete List of Authors:	Velasco Garrido, Marcial; Universitatsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Mette, Janika; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Mache, Stefanie; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Harth, Volker; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Preisser, Alexandra; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Occupational and environmental medicine
Keywords:	offshore, job demands, physical strains

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Title: Physical strains of offshore wind farm workers – a cross-sectional study.

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Subject heading: Occupational and environmental medicine

Keywords: offshore, job demands, physical strains

Word count: 3254

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Abstract

Objectives: To assess the physical strains of employees in the German offshore wind industry, according to job type and phase of the wind farm.

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: physical strains (e.g. ergonomics, vibration, heavy lifting).

Results: The most frequently mentioned physical strain was 'climbing' with 63.8% of the respondents reporting to be always or frequently confronted with climbing and ascending stairs during offshore work. Technician work was associated with a greater exposition to noise, vibrations, humidity, cold, heat, chemical substances, lifting/carrying heavy loads, transport of equipment, working in non-ergonomic positions and in cramped spaces, as well as climbing.

Indeed, statistical analyses showed that, after adjusting for phase of the wind farm, age, nationality, offshore experience, work schedule, and type of shift, technician work was associated with more frequently lifting/carrying of heavy loads (OR 2.58, 95% CI 1.58-4.23, p<0.001), transport of equipment (OR 2.06 95% CI 1.27-3.33, p=0.003), working with a twisted upper body (OR 2.85 95% CI 1.74-4.69, p<0.001), working overhead (OR 2.77 95% CI 1.67-4.58, p<0.001), and climbing (OR 2.30 95% CI 1.40-3.77, p=0.001). Also, in the adjusted model, working in wind farms under construction was strongly associated with increased and decreased exposure to humidity (OR

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2.32 95% CI 1.38-3.92, p=0.002) and poor air quality (OR 0.58 95% CI 0.35-0.95, p=0.029), respectively.

Conclusions: Workers on offshore wind farms comprise a heterogeneous group, including a wide variety of occupations. The degree of exposure to detrimental physical strains varies depending on the type of job. Technicians are more exposed to ergonomic challenges than other offshore workers.

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Strengths and limitations of this study

- Our study is one of the first to quantitatively assess physical strains of workers in the offshore wind industry.
- The study uncovers opportunities for interventions that could improve the health of offshore workers.
- The study design is cross-sectional; our findings must therefore be interpreted with caution and do not fulfil all causality criteria (e.g. lack temporality).

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Introduction

Since the construction of the first offshore wind farm in Vindeby, Denmark, in 1991 [1], the total capacity of offshore wind power has been continuously increasing worldwide. Indeed, the global cumulative offshore power capacity has grown in the past ten years from less than 1,000 megawatts (MW) in 2007 to more than 14,000 MW in 2017 [2]. Accordingly, there has also been a continuous increase in the workforce involved in the construction and operation of such offshore wind installations. Although the majority of offshore wind farms are located in the waters off of the coast of Europe, the industry is expanding rapidly to China, Vietnam, South Korea, Japan, India, and the US [3].

The offshore wind workplace is predominantly characterized by its remoteness and hostile environment: the average distance of the European installations from their respective coasts is currently 23.5 nautical miles (43.5 km) [3]. Typically, offshore wind farms consist of wind energy turbines, electric power transformation substations, and collector and converter substations, all spread over a variable water area. In Germany, the area of the wind farms ranges from 1 km² to more than 50 km² (with an average of 30 km²) [2].

Several professions are involved in the construction and operation of an offshore wind farm. In addition to the technical staff (electricians, mechanics, construction workers), site managers, caterers, and paramedics are also subjected to the unique offshore working and living conditions.

The dimensions and technical characteristics of the installations impose specific demands on the workforce. Currently, the turbines have an average height of 90 m and a rotor diameter of up to 150 m [4, 5]. As a result, working at extreme heights

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and in confined spaces, climbing, and carrying heavy equipment are unavoidable physical demands that employees are regularly confronted with [6].

The aim of our study was to assess the physical strains (e.g. ergonomics, vibration, heavy lifting) of employees in the offshore wind industry and to explore whether these physical demands differ according to job type (technicians and other jobs) or the phase of the wind farm (under construction and operation).

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Methods

Study design and population

An online cross-sectional survey was carried out between September 2016 and January 2017 of persons working on offshore wind farms located in the German exclusive economic zone (EEZ) of the North and Baltic Seas. By December 2016, there were 22 wind farms either already in operation or under construction in this area [2]. Although there are no exact data regarding the number of offshore workers involved in these installations, it has been estimated that up to 5,000 employees are directly or indirectly working on offshore wind farms within the German EEZ [7]. This represent our source population. In order to ensure our collective had sufficient exposure to the offshore environment, we restricted the sample to workers with regular offshore deployments or with a total of at least 28 days offshore during last year if working on an irregular schedule. Preliminary analyses showed that women (n = 28) differed statistically in many aspects when compared to men (data not shown). Females were thus excluded from further analyses.

Recruitment

Participation was anonymous and voluntary. Subjects were recruited by contacting offshore companies operating in the German EEZ via telephone and e-mail. We provided study information leaflets in both German and English through the channels of mail, e-mail, and personal communication to occupational physicians, health and safety managers, and human resources departments for distribution among their employees (e.g. via intranet, newsletters, e-mails, and word-of-mouth promotion). In addition, we promoted the study on relevant online platforms and forums. We also presented our study at the “Round-table Maritime Safety Partnership”, a regular

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meeting of key stakeholders organized by the German Offshore Wind Energy Foundation [8].

Questionnaire

The online questionnaire was designed with the platform SurveyMonkey®. It was accessible by electronic devices through its URL or QR-code, both provided in all written information materials (leaflets, e-mails, postings, etc.) used for recruitment. The questionnaire was available in German and English. The first page of the questionnaire provided information on the study aims and characteristics, as well as a required consent item to be filled out prior to data collection. Access to the questionnaire was only granted after ticking off the sentence "I hereby confirm that I have read and understood the study information and data protection policy above. I agree to participate". 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 discussed in this paper – required a median time of 24 minutes.

Sociodemographic variables

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

Job characteristics

We collected data on offshore experience ("less than 1 year" – "1 to 3 years" – "more

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than 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”), transportation arrangements from accommodations to workplace (“ship” – “helicopter” – “both” – “none, living and working on platform”), 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 a list of 18 physical demands and stressors during offshore deployments (modified from [9]). We included questions formatted as, “How often are you exposed to…[physical strain]?”. Answer possibilities were presented on a five-point Likert scale with the categories “always” – “often” – “sometimes” – “rarely” – “never/hardly ever”.

Statistics

Items left unanswered were treated as missing values and excluded from analysis. No imputation was done for any variable. Descriptive statistics are presented as frequencies and percentages for categorical variables. Bivariate associations were first explored with contingency tables. Bivariate and multivariate ordinal logistic regression was performed to take the ordering of the levels of exposure into account [10]. The statistical significance level was set at $p<0.05$. Statistical analyses were

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carried out using IBM® SPSS® Statistics (IBM Corp. released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.).

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Results

In total, 384 persons responded to the questionnaire (figure 1), although not all completed the entire 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 less than one year of work experience in this environment. Regarding specific occupations, technicians (operators, mechanics, and installers) represented the largest group (48.9%) followed by management staff (36.6%). The sample also included health and safety managers, paramedics, and platform and ship crew. Approximately two thirds of the responders were working on wind farms that were already operational (64.8%), while 35.2% were working on installations in the construction phase.

As expected due to the exclusion criteria of this study, workers with a regular schedule of 14 days offshore work and 14 days onshore leave were overrepresented (73.9%). Half of these worked rotating shifts. Only 13.7% had onshore accommodations during their offshore deployments.

Table 2 shows the prevalence of physical strains among survey respondents. Overall, the most frequently mentioned physical strain was 'climbing' with 63.8% of the respondents reporting to be either always or frequently confronted with climbing and ascending stairs during their offshore rotations. Noise was reported to be always or frequently present by 55.6% of the participants, followed by vibrations with 52.2%. Less frequent physical strains included working with reduced visibility, with 47.2% exposed either rarely or never, odors (46.0% rarely or never exposed), working with chemicals (41.3% rarely or never exposed), frequent changes between high and low

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temperatures (40.4% rarely or never exposed), and working overhead (40.2% rarely or never exposed). The distribution of the answers varied according to occupation with technicians reporting more frequent expositions to almost all strains (see table A1 in the supplementary file). Answers distribution also varied according to phase of the wind farm (see table A2 in the supplementary file).

Bivariate analysis showed statistically significant differences according to the type of occupation for several physical strains (see table 3). Working as a technician was associated with increased exposure to noise, vibrations, humidity, cold, heat, chemical substances, lifting/carrying of heavy loads, transport of equipment, working in non-ergonomic positions and cramped spaces as well as climbing compared to other offshore workers.

Furthermore, working on installations under construction was associated with greater exposure to humidity, cold, lifting/carrying of heavy loads, reduced visibility, working in cramped spaces, climbing, and unpredictable waiting times compared to working on operational wind farms. Bivariate analysis also showed that working on a wind farm under construction was associated with decreased exposure to poor air quality.

Following adjustment for phase of the wind farm, age, nationality, offshore experience, work schedule, and type of shift, technician work maintained a strong association with most of the above-mentioned physical strains. In particular, strong associations (OR > 2.0) were observed for lifting/carrying of heavy loads (OR 2.58, 95% CI 1.58-4.23, p<0.001), transport of equipment (OR 2.06 95% CI 1.27-3.33, p=0.003), working with a twisted upper body (OR 2.85 95% CI 1.74-4.69, p<0.001), working overhead (OR 2.77 95% CI 1.67-4.58, p<0.001), and climbing (OR 2.30 95% CI 1.40-3.77, p=0.001). In the adjusted model, phase of the wind farm also remained strongly associated with increased and decreased exposure to humidity (OR 2.32 95%

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CI 1.38-3.92, p=0.002) and poor air quality (OR 0.58 95% CI 0.35-0.95, p=0.029), respectively.

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Discussion

Despite the growing workforce involved in the construction and operation of offshore wind farms, little research has been done on this particular occupational group. Although considerable research exists on the working conditions, physical and psychological demands, and health issues of offshore workers from the offshore oil and gas industry, the physical strains experienced by employees in the offshore wind energy branch have thus far only been addressed in qualitative studies [11]. The offshore wind and offshore oil and gas sectors share many similarities, but there remain important differences between the two industries, such as the type of installations and the extensive area of wind farms requiring frequent transport during offshore deployments. There are also similarities with the work in the onshore wind sector – i.e. work in heights, climbing, type of installation – but comparability of both sectors is again limited due to the location of the installations, which demands for example the use of special safety and survival equipment during work. These differences justify a more in-depth investigation into this particular occupation and job environment. Overall, we found high levels of exposure (>50% of participants reporting being either always or often exposed) to climbing, noise and vibrations, and, albeit to a lesser extent, to handling heavy loads (42%). Although our data are not fully comparable to those of the European Working Conditions Survey 2015, the levels of exposure to noise, vibration, cold, heat, chemicals, and the handling of heavy loads appear to be higher than that of German high-skilled manual workers or within the construction and transportation sector [12]. To our knowledge, no data regarding climbing are available from such a study format (survey). In our sample, climbing was the most frequently reported physical strain, with 21.3% and 42.5% of offshore workers reporting to either always or often being required to climb,

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respectively. Within the group of technicians, this was observed to be 27.2% and 48.8%, respectively, a result that seems plausible in view of the dimensions of the installations (up to 115 m [4]). Vertical climbing, as is typically required on wind energy installations – both onshore and offshore – , is very physically demanding as additional muscular effort is required in order to maintain balance [13]. Although the use of fall-arrest systems obviously reduces the risk of major injury preventing falls from great heights, slipping and being caught in the confined spaces of the interior of wind energy installations remain very real hazards associated with climbing [14]. Offshore wind industry workers describe the climbing of ladders as being particularly challenging when combined with carrying heavy tools and wearing safety clothing (i.e., survival suits) [11], which is not required during work in onshore wind energy installations. The use of assist devices reduces climbing strain [15], while the presence of lifts obviously almost nullifies it. However, many older installations either do not have lifts or these are often inoperative, due to reparation or servicing.

We found patterns of physical and ergonomic strain for offshore wind workers to be associated with the type of job performed (technicians vs. other occupations). Differences in work-related factors among specific job groups have been previously described for offshore workers in the oil and gas industry [16] but, to our knowledge, not in the offshore wind industry. In particular, the technicians in our sample were subjected to higher degrees of working in non-ergonomic postures (overhead work, working with a twisted upper body or in forward flexion) during their assignments. They also were more frequently confronted with tasks involving heavy loads or bulky equipment, and were more often required to climb compared to offshore workers in other occupations. Although less frequently reported than the strain of climbing, overhead work and flexion and rotation of the upper body represent relevant

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ergonomic strains. Performing tasks in such awkward positions, heavy lifting, as well as the generally strenuous and physically demanding nature of the offshore work, particularly among technicians, is often unavoidable. It is well known that these factors are occupational risk factors for the development of musculoskeletal disorders [17], including workers in the offshore oil and gas industry [18]. Overhead work causes muscle fatigue of the shoulder joint and reduced grip force in the hand [19]. It has also been suggested to cause musculoskeletal pain in the neck and shoulder region [20], and is associated with arm and hand complaints [21]. There is evidence that exposure to combinations of overhead work, heavy lifting, and strenous work, as well as working in an awkward position (as observed for technicians in the offshore environment) all increase the risk of shoulder disorders [22]. In addition, frequent work involving flexion or rotation of the upper body is a prognostic factor for recurrent lower-back pain [23]. Lifting of heavy loads, particularly when associated with flexion and rotation of the trunk, is also associated with lower-back pain [24]. The relationship between lifting and moving heavy loads and lower-back disorders has been well established for specific occupations, such as construction workers [25, 26]. Since technicians are more exposed to such ergonomic constraints, they might be at higher risk for musculoskeletal disorders than other workers in the offshore wind energy industry might.

In contrast to the type of job, the associations between phase of the wind farm and the physical strains were rather weak. After adjusting the multivariate model to account for type of job – among other variables – the only strain which was strongly associated (OR > 2.0) with the construction phase was exposure to humidity and moisture. This seems plausible, as construction work often takes place outdoors and

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in close proximity to water, whereas, during the operation phase, a large proportion of the work is performed inside the turbines. Interestingly, decreased exposure to poor air quality and/or air-conditioning was observed during the construction phase. Again, this could be a reflection of the increased time spent outdoors compared to the operation phase.

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 have also been a problem concerning the frequency of exposition to physical strains, since some of the respondents filled out the survey while offshore (42.9% of the respondents). Indeed, for those workers who were offshore at the time of the survey, we observed a tendency to report exposure to some of the strains (transport of aids, overhead work, reduced visibility, working in cramped spaces, and climbing) less frequently (data not shown). This indicates that those answering while onshore may recall exposures to certain strains to be more frequent than they truly are. In other words, recall bias could have led to an overestimation of the overall degree of exposure to some of the physical strains (e.g., climbing or overhead work). Nevertheless, we do not expect recall bias to affect the observed differences in exposure between technicians and other jobs, since the proportion of workers responding to the questionnaire while offshore was similar among both groups (42.7% among technicians, 43.1% among the other jobs).

In addition, we cannot assess whether the respondents to our survey are representative of the population of workers at offshore wind farms. It has been estimated that approximately 5,000 persons are regularly or sporadically working on such installations in the German EEZ [7]. Based on this estimate, our study

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comprises roughly 5% of the total collective of offshore-wind workers in this area. A true response rate cannot be calculated, since the web survey was also promoted via online platforms/forums. Although there are no reliable data on the demographic characteristics of this group of German offshore wind industry workers, according to expert opinions (occupational physicians, health and safety managers), the gender distribution of the respondents to our survey does indeed correspond to the actual male to female ratio of the workforce. Since we excluded female employees in the detailed analyses of the health and working and living conditions of the study population, our results are only applicable to the male subgroup.

Finally, the use of SurveyMonkey® for conducting our survey implies data storage in the US, which could raise concerns regarding violations of data protection legislation in the European Union. Although the collected data comprised personal information (e.g., age, marital status, children, offshore experience, etc.), particular individuals are not identifiable. First, age information was collected in categories (i.e., birth dates were not recorded). Second, no information was collected on employers (i.e., company) or on the name of the wind farm or location (i.e., North Sea or Baltic Sea).

Furthermore, because the offshore wind energy industry is relatively young, there is a need for additional longitudinal research on the long-term effects of offshore work on the health and well-being of its employees.

Implications for clinicians and policy makers

Our findings have implications for occupational physicians and health safety managers taking care of offshore workers. Our results highlight the importance of possessing detailed knowledge of the specific job tasks and workplace conditions of employees when assessing fitness to work offshore and/or occupational risks. Indeed, jobs in the offshore wind industry differ substantially in terms of their physical demands, strains and associated health risks, and these differences must be considered in order to provide adequate and individually-tailored occupational medical advice. Particular attention needs to be put on the ergonomic strains of technicians when providing such council and when planning preventive and health promotion activities on offshore installations.

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Conclusions

Workers in the offshore wind industry comprise a heterogeneous group, which consists of a wide variety of occupations, including specific job tasks during the different phases of construction and operation, and work schedules, ranging from regular offshore commitments every two weeks with 12-hour shifts over 14 days, to sporadic deployments of only a few days. The degree of exposure to detrimental physical strains, therefore, also varies considerably depending on the type of job done offshore. Technicians in the offshore wind industry are more exposed to physical strains particularly relevant for the development of musculoskeletal complaints (e.g. climbing, heavy load lifting or overhead work) than other offshore workers. This aspect should be taken into account when when planning and providing interventions aiming to improve the working conditions of employees while offshore.

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Authors' contributions

AMP and SM conceived the study and led the application for funding. MVG and JM designed the survey with input from SM and AMP. MVG ran the 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.

Funding

Our work was supported by the German Federal Ministry of Education and Research (grant number: 01FA15029).

Competing interests

MVG, JM, SM, VH, and AMP declare that they have no competing interests.

Ethics

The study was approved by the Ethics Review Committee of the Hamburg Medical Association.

Acknowledgements

We thank all offshore workers who responded to the survey. We are also indebted to all company physicians, health and safety managers and all other staff who helped promote the survey.

We thank Rosalie McDonough for reviewing the paper. We also thank Robert Herold for statistical advice.

Data Sharing Statement

No additional data are available

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References

1. Nixon N. Timeline: The history of wind power. The Guardian, October 17th 2008. https://www.theguardian.com/environment/2008/oct/17/wind-power-renewable-energy (accessed 30 Sep 2017).
2. Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). Wind Monitor – Development in Germany. Kassel: IWES, 2016 http://windmonitor.iwes.fraunhofer.de/windmonitor_en/4_Offshore/1_zubau/2_entwicklung_in_deutschland/index.html (accessed 30 Sep 2017).
3. Global Wind Energy Council (GWEC). Global Wind Report 2016 – Annual market update. Brussels: GWEC, 2016 http://files.gwec.net/register?file=/files/GWR2016.pdf (accessed 30 Sep 2017).
4. Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). Wind Monitor – Turbines Size. Kassel: IWES, 2016 http://windmonitor.iwes.fraunhofer.de/windmonitor_en/4_Offshore/2_technik/3_Anlagengroesse/ (accessed 30 Sep 2017).
5. Stiftung Offshore Windenergie. Offshore Wind Energie – sauberer Strom aus dem Meer [Offshore wind energy - clean energy from the sea]. Varel: Stiftung Offshore Windenergie, 2016 http://www.offshore-stiftung.de/offshore-windenergie (accessed 30 Sep 2017).
6. Velasco Garrido M, Mette J, Mache S, Harth V, Preisser AM. Belastungen und Gefährdungen der Beschäftigten in der Offshore-Windindustrie [Demands and hazards of working in the offshore wind power industry]. Arbeitsmed Sozialmed Umweltmed 2017; 52(2): 134-137.
7. Federal Ministry for economic affairs and energy. Offshore wind energy – an overview of activities in Germany. Berlin: FMEAE, 2015 https://www.bmwi.de/Redaktion/EN/Publikationen/offshore-wind-energy.pdf?__blob=publicationFile&v=3 (accessed 30 Sep 2017).
8. Stiftung Offshore Windenergie. Vernetzung der maritimen Wirtschaft mit der Branche der Offshore-Windenergie 2 [Networking between maritime industry and offshore wind energy branch]. Varel: Stiftung Offshore Windenergie, 2017 https://www.offshore-stiftung.de/Vernetzung (accessed 30 Sep 2017).

For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

9. Bjerkan AM. Work, health and safety culture/climate. A study of employees in the Norwegian oil and gas industry. Oslo: Centre for Technology, Innovation and Culture, University of Oslo, 2010.

10. Kleinbaum DG, Klein M. Logistic Regression. A self-learning text. New York – Dordrecht – Heidelberg: 2010.

11. Mette J, Velasco Garrido M, Preisser AM, Harth V, Mache S. 'It's Still a Great Adventure' – Exploring Offshore Employees' Working Conditions in a Qualitative Study. J Occup Med Toxicol 2017; 12: 35.

12. European Foundation for the Improvement of Living and Working Conditions. European Working Conditions Survey 2015. Dublin: Eurofound, 2017 https://www.eurofound.europa.eu/data/european-working-conditions-survey (accessed 15 Dec 2017).

13. 'Barron PJ, Burgess K, Cooper K, Stewart AD. The effect of pitched and vertical ladder ergometer climbing on cardiorespiratory and psychophysical variables. Appl Ergon 2018; 66: 172-176 (Epub 2017 Sep 15).

14. Cooper K, Kirkpatrick P, Stewart A. Health effects associated with working in the wind power generation industry: a systematic review. JBI Database of Systematic Reviews and Implementation Reports 2014; 11: 327-373.

15. Barron PJ. Burgess K, Cooper K, Stewart AD. The physiological effect of a "climb assist" device on vertical ladder climbing. Ergonomics 2017; 60: 1008-1013.

16. Bjerkan AM. Work and health: a comparison between Norwegian onshore and offshore employees. Work 2011; 40: 125-142.

17. da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am J Ind Med. 2010; 53: 285–323.

18. Chen WQ, Yu ITS, Wong TW. Impact of occupational stress and other psychosocial factors on musculoskeletal pain among Chinese offshore oil installation workers. Occup Environ Med 2005; 62: 251-256.

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19. Kinali G, Kara S, Yildirim MS. Electromyographic analysis of an ergonomic risk factor: overhead work. J Phys Ther Sci 2016; 28: 1924-1927.

20. Shin SJ, An DH, Oh JS, Yoo WG. Changes in pressure pain in the upper trapezius muscle, cervical range of motion, and the cervical flexion–relaxation ratio after overhead work. Ind Health 2012; 50: 509-515.

21. Lowe BD, Shaw PB, Wilson SR, et al. Evaluation of a workplace exercise program for control of shoulder disorders in overhead assembly work. J Occup Environ Med 2017; 59: 563-570.

22. Linaker CH, Walker-Bone K. Shoulder disorders and occupation. Best Pract Res Clin Rheumatol 2015; 29: 405-23.

23. van den Heuve SG, Ariens GAM, Boshuizen HC, et al. Prognostic factors related to recurrent low-back pain and sickness absence. Scand J Work Environ Health 2004; 30: 459-467.

24. Hoogendoorn WE, van Poppel MNM, Bongers PM, Koes BW, Bouter LM. Physical load during work and leisure time as risk factors for back pain. Scand J Work Environ Health 1999; 25: 387-403. Fossum IN, Bjorvatn B, Waage S, Pallesen S. Effects of shift and night work in the offshore petroleum industry: a systematic review. Industrial Health 2013; 51: 530-544.

25. Vingard E, Alfredsson L, Fellenius E, Hogstedt C. Disability pensions due to musculoskeletal disorders among men in heavy occupations Scand J Soc Med 1992; 20: 31-36.

26. Stürmer T. Luessenhoop S, Neth A, et al. Construction work and low back disorders, preliminary findings of the Hamburg construction worker study. Spine 1997; 22: 2558-2563.

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Table 1. Demographic and occupational characteristics of all participants and subgroups (*only male with more than 28 days offshore)

Variable	Study population (n=268)	
	n	%
Age (n=268)		
20-34 years	116	43.4
35-49 years	122	45.5
⩾ 50 years	30	11.2
Nationality (n= 262)		
German	234	89.3
other	28	10.7
Offshore experience (n=267)		
< 1year	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
Transfer from accommodation to workplace (n=241)		
ship	76	28.9
helicopter	74	28.1
both	78	29.7
none (e.g. living and working on platform)	13	13.3

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Table 2. Prevalence of physical strains.

	Always		Often		Sometimes		Rarely		Never / hardly ever	
	n	%	n	%	n	%	n	%	n	%
Noise (n=252)	35	13.9	105	41.7	87	34.5	21	8.3	4	1.6
Vibrations/oscillation (n=255)	39	15.3	94	36.9	69	27.1	37	14.5	16	6.3
Humidity/moisture (n=254)	6	2.4	84	33.1	119	46.9	36	14.2	9	3.5
Cold (n=254)	3	1.2	73	28.7	145	57.1	25	9.8	8	3.1
Heat (n=254)	3	1.2	55	21.7	153	60.2	37	14.6	6	2.4
Frequent changes between heat and cold (n=252)	8	3.2	48	19.0	94	37.3	81	32.1	21	8.3
Odours (n=252)	7	2.8	41	16.3	88	34.9	90	35.7	26	10.3
Contact with chemicals or hazardous substances (n=252)	8	3.2	57	22.6	83	32.9	76	30.2	28	11.1
Lifting / carrying heavy loads (n=253)	16	6.3	90	35.6	86	34.0	51	20.2	17	6.7
Transport of aids (e. g. PPE, tools) over long distances (n=253)	44	17.4	76	30.0	73	28.9	43	17.0	17	6.7
Working with twisted upper body/forward flexion of the spine (n=254)	9	3.4	82	32.3	89	35.0	51	20.1	23	9.1
Working with unsupported raised arms (overhead work) (n=254)	1	0.4	44	17.3	107	42.1	70	27.6	32	12.6
Reduced visibility (n=252)	0	0.0	38	15.1	95	37.7	83	32.9	36	14.3
Closed/cramped quarters (n=253)	14	5.5	80	31.6	95	37.5	47	18.6	17	6.7
Climbing (n=254)	54	21.3	108	42.5	52	20.5	26	10.2	14	5.5
Poor air quality / air conditioning (n=253)	30	11.9	68	25.4	72	28.5	66	26.1	17	6.7
Restricted movement (n=254)	11	4.3	65	25.6	86	33.9	60	23.6	32	12.6
Unpredictable waiting times (e.g. during "weather days") (n=254)	6	2.4	92	36.2	111	43.7	39	15.4	6	2.4

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Table 3. Association between occupation, phase of the wind farm, and physical strains.

Physical strain	Crude OR (95% CI)	Adjusted OR (95% CI)[a]
Noise		
Occupation (technician)[#]	1.88 (1.19-2.99)**	1.72 (1.03-2.82)*
Phase of wind farm (under construction)[##]	1.52 (0.94-2.45)	1.31 (0,79-2,18)
Vibrations/oscillation		
Occupation (technician)[#]	1.75 (1.12-2.73)*	1.21 (0.75-1.96)
Phase of wind farm (under construction)[##]	1.48 (0.93-2.35)	1.25 (0.76-2.05)
Humidity/moisture		
Occupation (technician)[#]	1.89 (1.18-3.02)**	1.56 (0.94-2,57)
Phase of wind farm (under construction)[##]	2.63 (1.60-4.33)***	2.32 (1.38-3.92)**
Cold		
Occupation (technician)[#]	1.71 (1.05-2.78)*	1.68 (1.00-2.84)
Phase of wind farm (under construction)[##]	1.74 (1.05-2.88)*	1.59 (0,93-2,72)
Heat		
Occupation (technician)[#]	2.36 (1.42-3.92)**	1.83 (1.08-3.13)*
Phase of wind farm (under construction)[##]	1.34 (0.81-2.24)	1.02 (0.59-1.75)
Frequent changes between heat and cold		
Occupation (technician)[#]	1.42 (0.91-2.23)	1.36 (0.84-2.21)
Phase of wind farm (under construction)[##]	1.16 (0.72-1.85)	1.09 (0.66-1.79)
Odors		
Occupation (Technician)[#]	1.28 (0.82-2.01)	1.18 (0.73-1.92)
Phase of wind farm (under construction)[##]	1.09 (0.68-1.76)	1.00 (0.61-1.65)
Contact with chemicals or hazardous substances		
Occupation (technician)[#]	1.90 (1.21-2.99)**	1.76 (1.09-2.84)*
Phase of wind farm (under construction)[##]	0.82 (0.51-1.30)	0.79 (0.48-1.29)

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Lifting/carrying heavy loads (n=252)		
Occupation (technician)[#]	2.99 (1.53-3.78)***	2.58 (1.58-4,23)***
Phase of wind farm (under construction)[##]	1.70 (1.05-2.73)*	1.47 (0.89-2.43)
Transport of aids (e. g. PPE, tools) over long distances		
Occupation (technician)[#]	2.40 (1.53-3.78)***	2.06 (1.27-3.33)**
Phase of wind farm (under construction)[##]	1.25 (0.78-1.98)	0.99 (0.61-1.62)
Working with twisted upper body/forward flexion of the spine		
Occupation (technician)[#]	3.42 (2.14-5.48)***	2.85 (1.74-4.69)***
Phase of wind farm (under construction)[##]	1.50 (0.94-2.41)	1.32 (0.80-2.19)
Working with unsupported raised arms (overhead work)		
Occupation (technician)[#]	3.37 (2.10-5.43)***	2.77 (1.67-4.58)***
Phase of wind farm (under construction)[##]	1.38 (0.86-2.22)	1.13 (0.68-1.87)
Reduced visibility		
Occupation (technician)[#]	1.43 (0.91-2.25)	1.21 (0.74-1.96)
Phase of wind farm (under construction)[##]	2.18 (1.34-3.53)**	1.74 (1.05-2.89)*
Closed/cramped quarters		
Occupation (technician)[#]	2.14 (1.35-4.51)**	1.79 (1.10-2.93)*
Phase of wind farm (under construction)[##]	1.71 (1.06-2.75)*	1.48 (0.89-2-44)
Climbing (n=253)		
Occupation (technician)[#]	2.83 (1.71-4.51)***	2.30 (1.40-3.77)**
Phase of wind farm (under construction)[##]	2.08 (1.29-3.37)**	1.74 (1.05-2.89)*
Poor air quality/air conditioning		
Occupation technician)[#]	1.03 (0.66-1.61)	1.00 (0.62-1.60)
Phase of wind farm (under construction)[##]	0.61 (0.38-0.98)*	0.58 (0.35-0.95)*
Restricted movement		
Occupation (technician)[#]	0.94 (0.60-1.46)	0.70 (0.43-1.13)

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Phase of wind farm (under construction)[##]	1.18 (0.74-1.88)	0.99 (0.60-1.61)
Unpredictable waiting times (e.g. during "weather days")		
Occupation (technician)[#]	1.17 (0.74-1.85)	0.79 (0.48-1.31)
Phase of wind farm (under construction)[##]	2.08 (1.27-3.39)**	1.64 (0.97-2.76)

[#]reference: any other occupation; [##]reference: wind farm in operation
*p<0.05; **p<0.01; ***p<0.001
[a] Adjusted for age, nationality, offshore experience, work schedule and type of shift.

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Figure Legends

Figure 1. Study flow.

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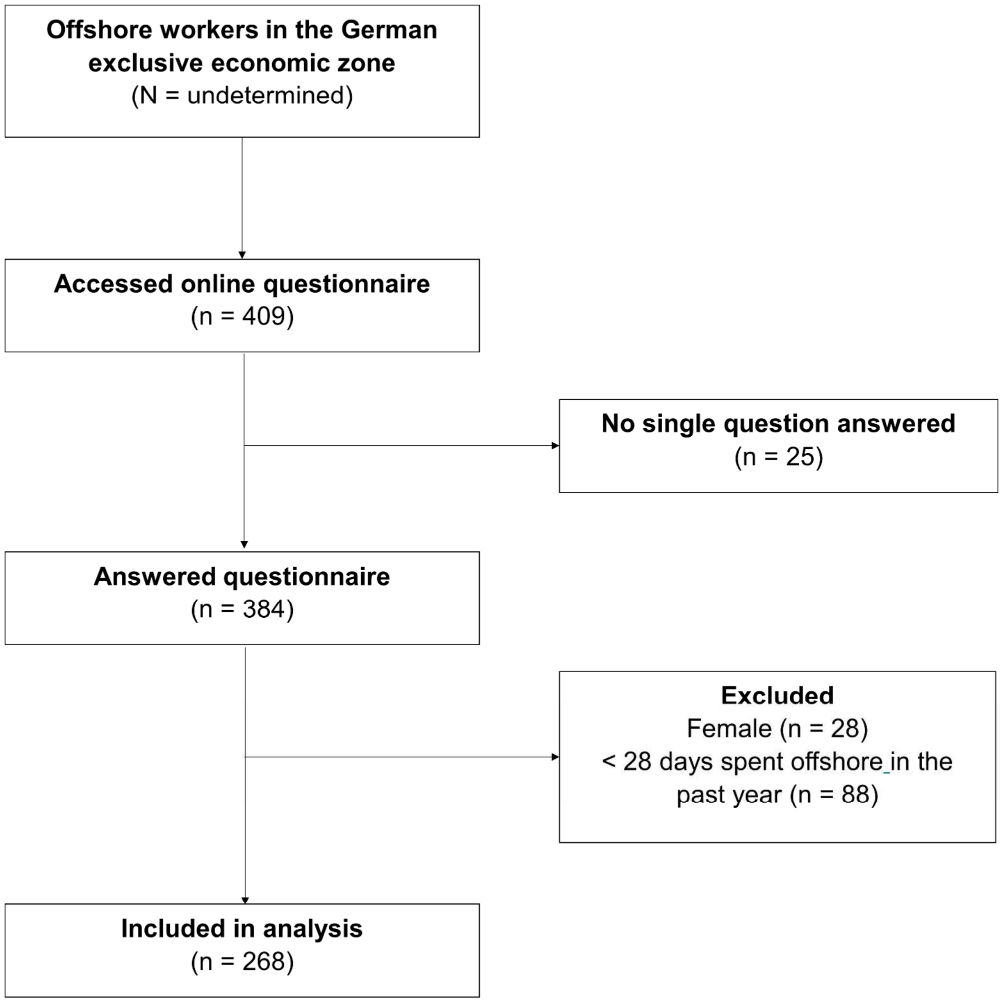

Figure 1. Study flow

277x277mm (300 x 300 DPI)

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Additional Tables

Table A1. Physical strains by occupation.

	Always		Often		Sometimes		Rarely		Never / hardly ever	
	n	%	n	%	n	%	n	%	n	%
Noise (n=252)										
Technicians	22	17.6	55	44.0	43	34.4	4	3.2	1	0.8
Other	13	10.2	50	39.4	44	34.6	17	13.4	3	2.4
Vibrations/oscillation (n=255)										
Technicians	21	16.7	54	42.9	32	25.4	16	12.7	3	2.4
Other	18	14.0	40	31.0	37	28.7	21	16.3	13	10.1
Humidity/moisture (n=254)										
Technicians	3	2.4	49	38.9	60	47.6	12	9.5	2	1.6
Other	3	2.3	35	27.3	59	46.1	24	18.8	7	5.5
Cold (n=254)										
Technicians	1	0.8	41	32.5	75	59.5	8	6.3	1	0.8
Other	2	1.6	32	25.0	70	54.7	17	13.3	7	5.5
Heat (n=254)										
Technicians	2	1.6	36	28.8	73	58.4	13	10.4	1	0.8
Other	1	0.8	19	14.7	80	62.0	24	18.6	5	3.9
Frequent changes between heat and cold (n=252)										
Technicians	5	4.0	24	19.4	51	41.1	37	29.8	7	5.6
Other	3	2.3	24	18.8	43	33.6	44	34.4	14	10.9
Odors (n=252)										
Technicians	3	2.4	21	17.1	47	38.2	42	34.1	10	8.1
Other	4	3.1	20	15.5	41	31.8	48	37.2	16	12.4
Contact with chemicals or hazardous substances (n=252)										
Technicians	4	3.3	36	29.3	42	34.1	31	25.2	10	8.1
Other	4	3.1	21	16.3	41	31.8	45	34.9	18	14.0
Lifting / carrying heavy loads (n=253)										
Technicians	9	7.2	58	46.4	44	35.2	12	9.6	2	1.6

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Other	7	5.5	32	25.0	42	32.8	39	30.5	8	6.3
Transport of aids (e. g. PPE, tools) over long distances (n=253)										
Technicians	30	24.0	44	35.2	28	22.4	20	16.0	3	2.4
Other	14	10.9	32	25.0	45	35.2	23	18.0	14	10.9
Working with twisted upper body/forward flexion of the spine (n=254)										
Technicians	5	4.0	57	45.6	42	33.6	18	14.4	3	2.4
Other	4	3.1	25	19.4	47	36.4	33	25.6	20	15.5
Working with unsupported raised arms (overhead work) (n=254)										
Technicians	1	0.8	30	24.0	61	48.8	29	23.2	4	3.2
Other	0	0.0	14	10.9	46	35.7	41	31.8	28	21.7
Reduced visibility (n=252)										
Technicians	0	0.0	17	13.8	55	44.7	39	31.7	12	9.8
Other	0	0.0	21	16.3	40	31.0	44	34.1	24	18.6
Closed/cramped quarters (n=253)										
Technicians	10	8.0	44	35.2	52	41.6	14	11.2	5	4.0
Other	4	3.1	36	28.1	43	33.6	33	25.8	12	9.4
Climbing (n=254)										
Technicians	34	27.2	61	48.8	23	18.4	6	4.8	1	0.8
Other	20	15.5	47	36.4	29	22.5	20	15.5	13	10.1
Poor air quality / air conditioning (n=253)										
Technicians	13	10.4	39	31.2	30	24.0	36	28.8	7	5.6
Other	17	13.3	29	22.7	42	32.8	30	23.4	10	7.8
Restricted movement (n=254)										
Technicians	4	3.2	31	24.8	44	35.2	33	26.4	13	10.4
Other	7	5.4	34	26.4	42	32.6	27	20.9	19	14.7
Unpredictable waiting times (e.g. during "weather days") (n=254)										
Technicians	4	3.2	46	36.8	54	43.2	20	16.0	1	0.8
Other	2	1.6	46	35.7	57	44.2	19	14.7	5	3.9

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Table A2. Physical strains by phase of the wind farm.

	Always		Often		Sometimes		Rarely		Never / hardly ever	
	n	%	n	%	n	%	n	%	n	%
Noise (n=251)										
Under construction	11	12.4	46	51.7	28	31.5	3	3.4	1	1.1
In operation	24	14.8	58	35.8	59	36.4	18	11.1	3	1.9
Vibrations/oscillation (n=254)										
Under construction	14	15.6	39	43.3	25	27.8	9	10.0	3	3.3
Other	25	15.2	55	33.5	44	26.8	27	16.5	13	7.9
Humidity/moisture (n=253)										
Under construction	3	3.3	43	47.8	34	37.8	9	10.0	1	1.1
In operation	3	1.8	41	25.2	84	51.5	27	16.6	8	4.9
Cold (n=253)										
Under construction	2	2.2	30	33.3	52	57.8	4	4.4	2	2.2
In operation	1	0.6	43	26.4	92	56.4	21	12.9	6	3.7
Heat (n=253)										
Under construction	3	3.3	21	23.3	52	57.8	13	14.4	1	1.1
In operation	0	0.0	34	20.9	100	61.3	24	14.7	5	3.1
Frequent changes between heat and cold (n=251)										
Under construction	2	2.2	19	21.3	34	38.2	28	31.5	6	6.7
In operation	6	3.7	29	17.9	59	36.4	53	32.7	15	9.3
Odors (n=251)										
Under construction	2	2.2	13	14.6	37	41.6	28	31.5	9	10.1
In operation	5	3.1	28	17.3	51	31.5	61	37.7	17	10.5
Contact with chemicals or hazardous substances (n=251)										
Under construction	3	3.4	16	18.0	32	36.0	27	30.3	11	12.4
In operation	5	3.1	41	25.3	51	31.5	48	29.6	17	10.5
Lifting / carrying heavy loads (n=252)										
Under construction	8	9.0	39	43.8	23	25.8	15	16.9	4	4.5
In operation	8	4.9	51	31.3	62	38.0	36	22.1	6	3.7
Transport of aids (e. g. PPE, tools) over long distances (n=252)										

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Under construction	17	19.3	28	31.8	24	27.3	15	17.0	4	4.5
In operation	27	16.5	48	29.3	48	29.3	28	17.1	13	7.9
Working with twisted upper body/forward flexion of the spine (n=253)										
Under construction	3	3.4	37	41.6	25	28.1	18	20.2	6	6.7
In operation	6	3.7	45	27.4	63	38.4	33	20.1	17	10.4
Working with unsupported raised arms (overhead work) (n=253)										
Under construction	1	1.1	19	21.3	35	39.3	27	30.3	7	7.9
In operation	0	0.0	25	15.2	71	43.3	43	26.2	25	15.2
Reduced visibility (n=251)										
Under construction	0	0.0	17	19.3	41	46.6	24	27.3	6	6.8
In operation	0	0.0	21	12.9	53	32.5	59	36.2	30	18.4
Closed/cramped quarters (n=252)										
Under construction	6	6.7	35	39.3	29	32.6	19	21.3	0	0.0
In operation	8	4.9	45	27.6	65	39.9	28	17.2	17	10.4
Climbing (n=253)										
Under construction	25	28.1	41	46.1	16	18.0	5	5.6	2	2.2
In operation	28	17.1	67	40.9	36	22.0	21	12.8	112	7.3
Poor air quality / air conditioning (n=252)										
Under construction	6	6.8	22	25.0	25	28.4	28	31.8	7	8.0
In operation	24	14.6	46	28.0	46	28.0	38	23.2	10	6.1
Restricted movement (n=253)										
Under construction	2	2.2	26	29.2	31	34.8	23	25.8	7	7.9
In operation	9	5.5	39	23.8	54	32.9	37	22.6	25	15.2
Unpredictable waiting times (e.g. during "weather days") (n=253)										
Under construction	2	2.2	41	46.1	39	43.8	6	6.7	1	1.1
In operation	4	2.4	51	31.1	71	43.3	33	20.1	5	3.0

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	**Item #**	**Recommendation**	**Reported on page #**
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	1,7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8,9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8,9
Bias	9	Describe any efforts to address potential sources of bias	*9,16*
Study size	10	Explain how the study size was arrived at	7 Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8,9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n.a.
		(*e*) Describe any sensitivity analyses	n.a.
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	All tables and figures
Outcome data	15*	Report numbers of outcome events or summary measures	11,12, tables 1,2,3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11,12, tables 2 and 3
		(*b*) Report category boundaries when continuous variables were categorized	n.a.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n.a.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n.a.
Discussion			
Key results	18	Summarise key results with reference to study objectives	13,14,15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16,17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-19
Generalisability	21	Discuss the generalisability (external validity) of the study results	16-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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BMJ Open

A cross-sectional survey of physical strains among offshore wind farm workers in the German exclusive economic zone

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-020157.R2
Article Type:	Research
Date Submitted by the Author:	02-Feb-2018
Complete List of Authors:	Velasco Garrido, Marcial; Universitatsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Mette, Janika; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Mache, Stefanie; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Harth, Volker; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health Preisser, Alexandra; Universitätsklinikum Hamburg-Eppendorf, Institute for Occupational and Maritime Health
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Occupational and environmental medicine
Keywords:	offshore, job demands, physical strains

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Title: A cross-sectional survey of physical strains among offshore wind farm workers in the German exclusive economic zone

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Subject heading: Occupational and environmental medicine

Keywords: offshore, job demands, physical strains

Word count: 3528

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Abstract

Objectives: To assess the physical strains of employees in the German offshore wind industry, according to job type and phase of the wind farm (under construction or operation).

Design: Web-based cross-sectional survey.

Setting: Offshore wind farm companies operating within the German exclusive economic zone.

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

Outcome measures: physical strains (e.g. climbing, noise, working overhead, with twisted upper body or in confined spaces, vibration, heavy lifting, humidity, odours).

Results: The most frequently mentioned physical strain was 'climbing' with 63.8% of the respondents reporting to be always or frequently confronted with climbing and ascending stairs during offshore work. Work as a technician was associated with a greater exposition to noise, vibrations, humidity, cold, heat, chemical substances, lifting/carrying heavy loads, transport of equipment, working in non-ergonomic positions and in cramped spaces, as well as climbing.

Indeed, statistical analyses showed that, after adjusting for phase of the wind farm, age, nationality, offshore experience, work schedule, and type of shift, compared to non-technicians, working as a technician was associated with more frequently lifting/carrying of heavy loads (OR 2.58, 95% CI 1.58-4.23), transport of equipment (OR 2.06 95% CI 1.27-3.33), working with a twisted upper body (OR 2.85 95% CI 1.74-4.69), working overhead (OR 2.77 95% CI 1.67-4.58), and climbing (OR 2.30 95% CI 1.40-3.77). Working in wind farms under construction was strongly associated with

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increased and decreased exposure to humidity (OR 2.32 95% CI 1.38-3.92) and poor air quality (OR 0.58 95% CI 0.35-0.95), respectively.

Conclusions: Workers on offshore wind farms constitute a heterogeneous group, including a wide variety of occupations. The degree of exposure to detrimental physical strains varies depending on the type of job. Technicians are more exposed to ergonomic challenges than other offshore workers.

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Strengths and limitations of this study

- Our study is one of the first to quantitatively assess physical strains of workers in the offshore wind industry.
- The study uncovers opportunities for interventions that could improve the health of offshore wind industry workers.
- The study design is cross-sectional and lacks of an external control group; our findings must therefore be interpreted with caution and do not fulfil all causality criteria (e.g. lack temporality).
- We cannot exclude, that the generalizability of our results is limited since we due to the lack of data on the offshore wind farm workforce we cannot address the representativity of our sample.

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Introduction

Since the construction of the first offshore wind farm in Vindeby, Denmark, in 1991 [1], the total capacity of offshore wind power has been continuously increasing worldwide. Indeed, the global cumulative offshore power capacity has grown in the past ten years from less than 1,000 megawatts (MW) in 2007 to more than 14,000 MW in 2017 [2]. Accordingly, there has also been a continuous increase in the workforce involved in the construction and operation of such offshore wind installations. Although the majority of offshore wind farms are located in the waters off the coast of Europe, the industry is expanding rapidly to China, Vietnam, South Korea, Japan, India, and the US [3].

The offshore wind workplace is predominantly characterized by its remoteness and hostile environment: the average distance of the European installations from their respective coasts is currently 23.5 nautical miles (43.5 km) [3]. Offshore wind farms in the German exclusive economic zone (EEZ) are located up to 62 nautical miles (115 km) from the coast (in average 34 nautical miles in the North Sea) [2] mandating overnight accommodation. Typically, offshore wind farms consist of wind energy turbines, electric power transformation substations, and collector and converter substations, all spread over a variable water area. In Germany, the area of the wind farms ranges from 1 km² to more than 50 km² (with an average of 30 km²) [2]. The German offshore wind industry is considered to be one of the most developed worldwide [3].

Several professions are involved in the construction and operation of an offshore wind farm. In addition to the technical staff (electricians, mechanics, construction workers), site managers, caterers, and paramedics are also subjected to the unique offshore working and living conditions.

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The dimensions and technical characteristics of the installations impose specific demands on the workforce. Currently, the turbines have an average height of 90 m and a rotor diameter of up to 150 m [4, 5]. As a result, working at extreme heights and in confined spaces, climbing, and carrying heavy equipment are unavoidable physical demands that employees are regularly confronted with [6].

The aim of our study was to assess the physical strains (e.g. working in akward body positions, noise, vibration, heavy lifting) of employees in the offshore wind industry and to explore whether these physical demands differ according to job type (technicians and other jobs) or the phase of the wind farm (under construction and operation).

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Methods

Study design and population

An online cross-sectional survey was carried out between September 2016 and January 2017 of persons working on offshore wind farms located in the German EEZ of the North and Baltic Seas. By December 2016, there were 22 wind farms either already in operation or under construction in this area [2]. Although there are no exact data regarding the number of offshore workers involved in these installations, it has been estimated that up to 5,000 employees are directly or indirectly working on offshore wind farms within the German EEZ [7]. This represents our source population. In order to ensure that our sample had sufficient exposure to the offshore environment, we restricted the sample to workers with regular offshore deployments or with a total of at least 28 days offshore during the last year if working on an irregular schedule (28 days represent round 10% of working days on a regular year) Preliminary analyses showed that women (n = 28) differed statistically in many aspects when compared to men (data not shown). Female workers were thus excluded from further analyses.

Recruitment

Participation was anonymous and voluntary. Subjects were recruited by contacting offshore companies operating in the German EEZ via telephone and e-mail. We provided study information leaflets in both German and English through the channels of mail, e-mail, and personal communication to occupational physicians, health and safety managers, and human resources departments for distribution among their employees (e.g. via intranet, newsletters, e-mails, and word-of-mouth promotion). In addition, we promoted the study on relevant online platforms and forums. We also

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presented our study at the “Round-table Maritime Safety Partnership”, a regular meeting of key stakeholders organized by the German Offshore Wind Energy Foundation [8].

Questionnaire

The online questionnaire was designed with the platform SurveyMonkey®. It was accessible by electronic devices through its URL or QR-code, both provided in all written information materials (leaflets, e-mails, postings, etc.) used for recruitment. The questionnaire was available in German and English. The first page of the questionnaire provided information on the study aims and characteristics, as well as a required consent item to be filled out prior to data collection. Access to the questionnaire was only granted after ticking off the sentence “I hereby confirm that I have read and understood the study information and data protection policy above. I agree to participate”. Termination of the survey was possible at any stage. The questionnaire was piloted and refined with the help of offshore wind workers. Completion of the questionnaire – including topics and instruments not discussed in this paper – required a median time of 24 minutes.

Sociodemographic variables

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

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Job characteristics

We collected data on offshore experience (“less than 1 year” – “1 to 3 years” – “more than 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”), transportation arrangements from accommodation to workplace (“ship” – “helicopter” – “both” – “none, living and working on platform”), location of accommodation (“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 a list of 18 physical demands and stressors: “noise”, “vibrations/oscillation”, “humidity/moisture”, “cold”, “heat”, “frequent changes between heat and cold”, “odours”, “contact with chemicals or hazardous substances”, “lifting/carrying heavy loads”, “transport of aids (e. g. PPE, tools) over long distances”, “working with twisted upper body/forward flexion of the spine”, “working with unsupported raised arms (overhead work)”, “reduced visibility”, “closed/cramped quarters”, “climbing”, “poor air quality/air conditioning”, “restricted movement”, “unpredictable waiting times (e.g. during "weather days")” (see supplementary material) during offshore deployments (modified from Bjerkan [9]). We included questions formatted as, “How often are you exposed to…[physical strain]?”. Answer possibilities were presented on a five-point Likert scale with the categories “always” – “often” – “sometimes” – “rarely” – “never/hardly ever”.

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Statistics

Items left unanswered were treated as missing values and excluded from analysis. No imputation was done for any variable. Descriptive statistics are presented as frequencies and percentages for categorical variables. Bivariate and multivariate ordinal logistic regression was performed to estimate odds ratios (OR) with 95% confidence intervals (95%-CI) for each physical strain according to occupation and phase of the wind farm adjusting for age, nationality, offshore experience, work schedule and type of shift. We chose and ordinal logistic regression approach (in opposition to a dichotomous) to exploit the ordered levels of the dependent variables (physical strains) [10]. The statistical significance level was set at $p<0.05$. Statistical analyses were carried out using IBM® SPSS® Statistics (IBM Corp. released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.).

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Results

In total, 384 persons responded to the questionnaire (figure 1), although not all completed the entire 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 less than one year of work experience in this environment. Regarding specific occupations, technicians (operators, mechanics, and installers) represented the largest group (48.9%) followed by management staff (36.6%). The sample also included health and safety managers, paramedics, and platform and ship crew. Approximately two thirds of the responders were working on wind farms that were already operational (64.8%), while 35.2% were working on installations in the construction phase.

As expected due to the exclusion criteria of this study, workers with a regular schedule of 14 days offshore work and 14 days onshore leave were overrepresented (73.9%). Half of these worked rotating shifts. Only 13.7% had onshore accommodations during their offshore deployments.

Table 2 shows the prevalence of physical strains among survey respondents. Overall, the most frequently mentioned physical strain was ’climbing’ with 63.8% of the respondents reporting to be either always or often confronted with climbing and ascending stairs during their offshore rotations. Noise was reported to be always or often present by 55.6% of the participants, followed by vibrations with 52.2%. Less frequent physical strains included working with reduced visibility, with 47.2% exposed either rarely or never, odours (46.0% rarely or never exposed), working with chemicals (41.3% rarely or never exposed), frequent changes between high and low

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temperatures (40.4% rarely or never exposed), and working overhead (40.2% rarely or never exposed). The distribution of the answers varied according to occupation with technicians reporting more frequent expositions to almost all strains (see table A1 in the supplementary file). Answers distribution also varied according to phase of the wind farm (see table A2 in the supplementary file).

Bivariate analysis showed statistically significant differences according to the type of occupation for several physical strains (see table 3). Working as a technician was associated with increased exposure to noise, vibrations, high humidity, cold, heat, chemical substances, lifting/carrying of heavy loads, transport of equipment, working in non-ergonomic positions and cramped spaces as well as climbing compared to other offshore workers.

Furthermore, working on installations under construction was associated with greater exposure to high humidity, cold, lifting/carrying of heavy loads, reduced visibility, working in cramped spaces, climbing, and unpredictable waiting times compared to working on operational wind farms. Bivariate analysis also showed that working on a wind farm under construction was associated with decreased exposure to poor air quality.

Following adjustment for phase of the wind farm, age, nationality, offshore experience, work schedule, and type of shift, technician work maintained a strong association with most of the above-mentioned physical strains. In particular, strong associations (OR > 2.0) were observed for lifting/carrying of heavy loads (OR 2.58, 95% CI 1.58-4.23, p<0.001), transport of equipment (OR 2.06 95% CI 1.27-3.33, p=0.003), working with a twisted upper body (OR 2.85 95% CI 1.74-4.69, p<0.001), working overhead (OR 2.77 95% CI 1.67-4.58, p<0.001), and climbing (OR 2.30 95% CI 1.40-3.77, p=0.001). In the adjusted model, phase of the wind farm also remained

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strongly associated with increased and decreased exposure to humidity (OR 2.32 95% CI 1.38-3.92, p=0.002) and poor air quality (OR 0.58 95% CI 0.35-0.95, p=0.029), respectively.

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Discussion

Despite the growing workforce involved in the construction and operation of offshore wind farms, little research has been done on this particular occupational group. Although considerable research exists on the working conditions, physical and psychological demands, and health issues of offshore workers from the offshore oil and gas industry [11], the physical strains experienced by employees in the offshore wind energy branch have thus far only been addressed in qualitative studies [12]. The offshore wind and offshore oil and gas sectors share many similarities, but there remain important differences between the two industries, such as the type of installations and the extensive area of wind farms requiring frequent transport during offshore deployments. There are also similarities with the work in the onshore wind sector – i.e. work in heights, climbing, type of installation – but comparability of both sectors is again limited due to the location of the installations, which demands for example the use of special safety and survival equipment during work. These differences justify a more in-depth investigation into this particular occupation and job environment.

Overall, we found high levels of exposure (>50% of participants reporting being either always or often exposed) to climbing, noise and vibrations, and, albeit to a lesser extent, to handling heavy loads (42%). Although our data are not fully comparable to those of the European Working Conditions Survey 2015, the levels of exposure to noise, vibration, cold, heat, chemicals, and the handling of heavy loads appear to be higher than that of German high-skilled manual workers or within the construction and transportation sector [13]. To our knowledge, no data regarding climbing are available from such a study format (survey). In our sample, climbing was the most frequently reported physical strain, with 21.3% and 42.5% of offshore workers

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reporting to either always or often being required to climb, respectively. Within the group of technicians, this was observed to be 27.2% and 48.8%, respectively, a result that seems plausible in view of the dimensions of the installations (up to 115 m height [4]). Vertical climbing, as is typically required on wind energy installations – both onshore and offshore – , is very physically demanding as additional muscular effort is required in order to maintain balance [14]. Although the use of fall-arrest systems obviously reduces the risk of major injury by preventing falls from great heights, slipping and being caught in the confined spaces of the interior of wind energy installations remain very real hazards associated with climbing [15]. Offshore wind industry workers describe the climbing of ladders as being particularly challenging when combined with carrying heavy tools and wearing safety clothing (i.e., survival suits) [12], which is not required during work in onshore wind energy installations. The use of assist devices reduces climbing strain [16], while the presence of lifts obviously almost nullifies it. However, many older installations either do not have lifts or these are often inoperative, due to reparation or servicing.

We found patterns of physical and ergonomic strain for offshore wind workers to be associated with the type of job performed (technicians vs. other occupations). Differences in work-related factors among specific job groups have been previously described for offshore workers in the oil and gas industry [17] but, to our knowledge, not in the offshore wind industry. In particular, the technicians in our sample were subjected to higher degrees of working in non-ergonomic postures (overhead work, working with a twisted upper body or in forward flexion) during their assignments. They also were more frequently confronted with tasks involving heavy loads or bulky equipment, and were more often required to climb compared to offshore workers in other occupations. Although less frequently reported than the strain of climbing,

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overhead work and flexion and rotation of the upper body represent relevant ergonomic strains. Performing tasks in such awkward positions, heavy lifting, as well as the generally strenuous and physically demanding nature of the offshore work, particularly among technicians, is often unavoidable. It is well known that these factors are occupational risk factors for the development of musculoskeletal disorders [18], including workers in the offshore oil and gas industry [19]. Overhead work causes muscle fatigue of the shoulder joint and reduced grip force in the hand [20]. It has also been suggested to cause musculoskeletal pain in the neck and shoulder region [21], and is associated with arm and hand complaints [22]. There is evidence that exposure to combinations of overhead work, heavy lifting, and strenous work, as well as working in an awkward position (as observed for technicians in the offshore environment) all increase the risk of shoulder disorders [23]. In addition, frequent work involving flexion or rotation of the upper body is a prognostic factor for recurrent lower-back pain [24]. Lifting of heavy loads, particularly when associated with flexion and rotation of the trunk, is also associated with lower-back pain [25]. The relationship between lifting and moving heavy loads and lower-back disorders has been well established for specific occupations, such as construction workers [26, 27]. Since technicians are more exposed to such ergonomic constraints, they might be at higher risk for musculoskeletal disorders than other workers in the offshore wind energy industry might.

In contrast to the type of job, the associations between phase of the wind farm and the physical strains were rather weak. After adjusting the multivariate model to account for type of job – among other variables – the only factor which was strongly associated (OR > 2.0) with the construction phase was exposure to humidity and

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moisture. This seems plausible, as construction work often takes place outdoors and in close proximity to water, whereas, during the operation phase, a large proportion of the work is performed inside the turbines. Interestingly, decreased exposure to poor air quality and/or air-conditioning was observed during the construction phase. Again, this could be a reflection of the increased time spent outdoors compared to the operation phase.

Limitations

The main limitation of our study is its cross-sectional design, which prohibits the establishment of sound causal links in the associations observed. In addition, our study lacks of an external control group from other occupational groups. Nevertheless, our internal comparison between technicians and non-technicians allows to identify different patterns of physical strains within offshore wind park workers.

Recall bias may have also been a problem concerning the frequency of exposition to physical strains, since some of the respondents filled out the survey while offshore (42.9% of the respondents). Indeed, for those workers who were offshore at the time of the survey, we observed a tendency to report exposure to some of the strains (transport of aids, overhead work, reduced visibility, working in cramped spaces, and climbing) less frequently (data not shown). This indicates that those answering while onshore may recall exposures to certain strains to be more frequent than they truly are. In other words, recall bias could have led to an overreporting of the overall degree of exposure to some of the physical strains (e.g., climbing or overhead work). Nevertheless, we do not expect recall bias to affect the observed differences in exposure between technicians and other jobs, since the proportion of workers

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responding to the questionnaire while offshore was similar among both groups (42.7% among technicians, 43.1% among the other jobs).

In addition, we cannot assess whether the respondents to our survey are representative of the population of workers at offshore wind farms, thus we cannot exclude selection bias leading to limited generalizability. It has been estimated that approximately 5,000 persons are regularly or sporadically working on such installations in the German EEZ [7]. Based on this estimate, our study comprises roughly 5% of the total collective of offshore-wind workers in this area. A true response rate cannot be calculated, since the web survey was also promoted via online platforms/forums. Although there are no reliable data on the demographic characteristics of this group of German offshore wind industry workers, according to expert opinions (occupational physicians, health and safety managers), the gender distribution of the respondents to our survey does indeed correspond to the actual male to female ratio of the workforce in this sector. Since we excluded female workers in the detailed analyses of the health and working and living conditions of the study population, our results are only applicable to the male offshore wind farm workers.

Finally, the use of SurveyMonkey® for conducting our survey implies data storage in the US, which could raise concerns regarding violations of data protection legislation in the European Union. Although the collected data comprised personal information (e.g., age, marital status, children, offshore experience, etc.), particular individuals are not identifiable. First, age information was collected in categories (i.e., birth dates were not recorded). Second, no information was collected on employers (i.e., company) or on the name of the wind farm or location (i.e., North Sea or Baltic Sea).

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Furthermore, because the offshore wind energy industry is relatively young, there is a need for additional longitudinal research on the long-term effects of offshore work on the health and well-being of its employees.

Implications for clinicians and policy makers

Our findings have implications for occupational physicians and health safety managers taking care of offshore workers. Our results highlight the importance of possessing detailed knowledge of the specific job tasks and workplace conditions of employees when assessing fitness to work offshore and/or occupational risks. Indeed, jobs in the offshore wind industry differ substantially in terms of their physical demands, strains and associated health risks, and these differences must be considered in order to provide adequate and individually-tailored occupational medical advice. Particular attention needs to be put on the ergonomic strains of technicians when providing such counsel and when planning preventive and health promotion activities on offshore installations.

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Conclusions

Workers in the offshore wind industry comprise a heterogeneous group, which consists of a wide variety of occupations, including specific job tasks during the different phases of construction and operation, and work schedules, ranging from regular offshore commitments every two weeks with 12-hour shifts over 14 days, to sporadic deployments of only a few days. The degree of exposure to detrimental physical strains, therefore, also varies considerably depending on the type of job done offshore. Technicians in the offshore wind industry are more exposed to physical strains (e.g. climbing, heavy load lifting or overhead work) particularly relevant for the development of musculoskeletal complaints than other offshore workers. This aspect should be taken into account when planning and providing interventions aiming to improve the working conditions of employees while offshore.

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Authors' contributions

AMP and SM conceived the study and led the application for funding. MVG and JM designed the survey with input from SM and AMP. MVG ran the 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.

Funding

Our work was supported by the German Federal Ministry of Education and Research (grant number: 01FA15029).

Competing interests

MVG, JM, SM, VH, and AMP declare that they have no competing interests.

Ethics

The study was approved by the Ethics Review Committee of the Hamburg Medical Association.

Acknowledgements

We thank all offshore workers who responded to the survey. We are also indebted to all company physicians, health and safety managers and all other staff who helped promote the survey.

We thank Rosalie McDonough for reviewing the paper. We also thank Robert Herold for statistical advice.

Data Sharing Statement

No additional data are available

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References

1. Nixon N. Timeline: The history of wind power. The Guardian, October 17th 2008. https://www.theguardian.com/environment/2008/oct/17/wind-power-renewable-energy (accessed 30 Sep 2017).
2. Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). Wind Monitor – Development in Germany. Kassel: IWES, 2016 http://windmonitor.iwes.fraunhofer.de/windmonitor_en/4_Offshore/1_zubau/2_entwicklung_in_deutschland/index.html (accessed 30 Sep 2017).
3. Global Wind Energy Council (GWEC). Global Wind Report 2016 – Annual market update. Brussels: GWEC, 2016 http://files.gwec.net/register?file=/files/GWR2016.pdf (accessed 30 Sep 2017).
4. Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). Wind Monitor – Turbines Size. Kassel: IWES, 2016 http://windmonitor.iwes.fraunhofer.de/windmonitor_en/4_Offshore/2_technik/3_Anlagengroesse/ (accessed 30 Sep 2017).
5. Stiftung Offshore Windenergie. Offshore Wind Energie – sauberer Strom aus dem Meer [Offshore wind energy - clean energy from the sea]. Varel: Stiftung Offshore Windenergie, 2016 http://www.offshore-stiftung.de/offshore-windenergie (accessed 30 Sep 2017).
6. Velasco Garrido M, Mette J, Mache S, Harth V, Preisser AM. Belastungen und Gefährdungen der Beschäftigten in der Offshore-Windindustrie [Demands and hazards of working in the offshore wind power industry]. Arbeitsmed Sozialmed Umweltmed 2017; 52(2): 134-137.
7. Federal Ministry for economic affairs and energy. Offshore wind energy – an overview of activities in Germany. Berlin: FMEAE, 2015 https://www.bmwi.de/Redaktion/EN/Publikationen/offshore-wind-energy.pdf?__blob=publicationFile&v=3 (accessed 30 Sep 2017).
8. Stiftung Offshore Windenergie. Vernetzung der maritimen Wirtschaft mit der Branche der Offshore-Windenergie 2 [Networking between maritime industry and offshore wind energy branch]. Varel: Stiftung Offshore Windenergie, 2017 https://www.offshore-stiftung.de/Vernetzung (accessed 30 Sep 2017).

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9. Bjerkan AM. Work, health and safety culture/climate. A study of employees in the Norwegian oil and gas industry. Oslo: Centre for Technology, Innovation and Culture, University of Oslo, 2010.

10. Kleinbaum DG, Klein M. Logistic Regression. A self-learning text. New York – Dordrecht – Heidelberg: 2010.

11. Gardner R. Overview and characteristics of some occupational exposures and health risks on offshore oil and gas installations. Arch Occup Hyg 2003; 47: 201-210.

12. Mette J, Velasco Garrido M, Preisser AM, Harth V, Mache S. 'It's Still a Great Adventure' – Exploring Offshore Employees' Working Conditions in a Qualitative Study. J Occup Med Toxicol 2017; 12: 35.

13. European Foundation for the Improvement of Living and Working Conditions. European Working Conditions Survey 2015. Dublin: Eurofound, 2017 https://www.eurofound.europa.eu/data/european-working-conditions-survey (accessed 15 Dec 2017).

14. 'Barron PJ, Burgess K, Cooper K, Stewart AD. The effect of pitched and vertical ladder ergometer climbing on cardiorespiratory and psychophysical variables. Appl Ergon 2018; 66: 172-176 (Epub 2017 Sep 15).

15. Cooper K, Kirkpatrick P, Stewart A. Health effects associated with working in the wind power generation industry: a systematic review. JBI Database of Systematic Reviews and Implementation Reports 2014; 11: 327-373.

16. Barron PJ. Burgess K, Cooper K, Stewart AD. The physiological effect of a "climb assist" device on vertical ladder climbing. Ergonomics 2017; 60: 1008-1013.

17. Bjerkan AM. Work and health: a comparison between Norwegian onshore and offshore employees. Work 2011; 40: 125-142.

18. da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am J Ind Med. 2010; 53: 285–323.

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19. Chen WQ, Yu ITS, Wong TW. Impact of occupational stress and other psychosocial factors on musculoskeletal pain among Chinese offshore oil installation workers. Occup Environ Med 2005; 62: 251-256.

20. Kinali G, Kara S, Yildirim MS. Electromyographic analysis of an ergonomic risk factor: overhead work. J Phys Ther Sci 2016; 28: 1924-1927.

21. Shin SJ, An DH, Oh JS, Yoo WG. Changes in pressure pain in the upper trapezius muscle, cervical range of motion, and the cervical flexion–relaxation ratio after overhead work. Ind Health 2012; 50: 509-515.

22. Lowe BD, Shaw PB, Wilson SR, et al. Evaluation of a workplace exercise program for control of shoulder disorders in overhead assembly work. J Occup Environ Med 2017; 59: 563-570.

23. Linaker CH, Walker-Bone K. Shoulder disorders and occupation. Best Pract Res Clin Rheumatol 2015; 29: 405-23.

24. van den Heuve SG, Ariens GAM, Boshuizen HC, et al. Prognostic factors related to recurrent low-back pain and sickness absence. Scand J Work Environ Health 2004; 30: 459-467.

25. Hoogendoorn WE, van Poppel MNM, Bongers PM, Koes BW, Bouter LM. Physical load during work and leisure time as risk factors for back pain. Scand J Work Environ Health 1999; 25: 387-403. Fossum IN, Bjorvatn B, Waage S, Pallesen S. Effects of shift and night work in the offshore petroleum industry: a systematic review. Industrial Health 2013; 51: 530-544.

26. Vingard E, Alfredsson L, Fellenius E, Hogstedt C. Disability pensions due to musculoskeletal disorders among men in heavy occupations Scand J Soc Med 1992; 20: 31-36.

27. Stürmer T. Luessenhoop S, Neth A, et al. Construction work and low back disorders, preliminary findings of the Hamburg construction worker study. Spine 1997; 22: 2558-2563.

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Table 1. Demographic and occupational characteristics of all participants and subgroups (*only male with more than 28 days offshore)

Variable	Study population (n=268) n	%
Age (n=268)		
20-34 years	116	43.4
35-49 years	122	45.5
⩾ 50 years	30	11.2
Nationality (n= 262)		
German	234	89.3
other	28	10.7
Offshore experience (n=267)		
< 1year	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
Transfer from accommodation to workplace (n=241)		
ship	76	28.9
helicopter	74	28.1
both	78	29.7
none (e.g. living and working on platform)	13	13.3

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Table 2. Prevalence of physical strains.

	Always		Often		Sometimes		Rarely		Never / hardly ever	
	n	%	n	%	n	%	n	%	n	%
Noise (n=252)	35	13.9	105	41.7	87	34.5	21	8.3	4	1.6
Vibrations/oscillation (n=255)	39	15.3	94	36.9	69	27.1	37	14.5	16	6.3
Humidity/moisture (n=254)	6	2.4	84	33.1	119	46.9	36	14.2	9	3.5
Cold (n=254)	3	1.2	73	28.7	145	57.1	25	9.8	8	3.1
Heat (n=254)	3	1.2	55	21.7	153	60.2	37	14.6	6	2.4
Frequent changes between heat and cold (n=252)	8	3.2	48	19.0	94	37.3	81	32.1	21	8.3
Odours (n=252)	7	2.8	41	16.3	88	34.9	90	35.7	26	10.3
Contact with chemicals or hazardous substances (n=252)	8	3.2	57	22.6	83	32.9	76	30.2	28	11.1
Lifting / carrying heavy loads (n=253)	16	6.3	90	35.6	86	34.0	51	20.2	17	6.7
Transport of aids (e. g. PPE, tools) over long distances (n=253)	44	17.4	76	30.0	73	28.9	43	17.0	17	6.7
Working with twisted upper body/forward flexion of the spine (n=254)	9	3.4	82	32.3	89	35.0	51	20.1	23	9.1
Working with unsupported raised arms (overhead work) (n=254)	1	0.4	44	17.3	107	42.1	70	27.6	32	12.6
Reduced visibility (n=252)	0	0.0	38	15.1	95	37.7	83	32.9	36	14.3
Closed/cramped quarters (n=253)	14	5.5	80	31.6	95	37.5	47	18.6	17	6.7
Climbing (n=254)	54	21.3	108	42.5	52	20.5	26	10.2	14	5.5
Poor air quality / air conditioning (n=253)	30	11.9	68	25.4	72	28.5	66	26.1	17	6.7
Restricted movement (n=254)	11	4.3	65	25.6	86	33.9	60	23.6	32	12.6
Unpredictable waiting times (e.g. during "weather days") (n=254)	6	2.4	92	36.2	111	43.7	39	15.4	6	2.4

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Table 3. Association between occupation, phase of the wind farm, and physical strains.

Physical strain	Crude OR (95% CI)	Adjusted OR (95% CI)[a]
Noise		
Occupation (technician)[#]	1.88 (1.19-2.99)**	1.72 (1.03-2.82)*
Phase of wind farm (under construction)[##]	1.52 (0.94-2.45)	1.31 (0,79-2,18)
Vibrations/oscillation		
Occupation (technician)[#]	1.75 (1.12-2.73)*	1.21 (0.75-1.96)
Phase of wind farm (under construction)[##]	1.48 (0.93-2.35)	1.25 (0.76-2.05)
Humidity/moisture		
Occupation (technician)[#]	1.89 (1.18-3.02)**	1.56 (0.94-2,57)
Phase of wind farm (under construction)[##]	2.63 (1.60-4.33)***	2.32 (1.38-3.92)**
Cold		
Occupation (technician)[#]	1.71 (1.05-2.78)*	1.68 (1.00-2.84)
Phase of wind farm (under construction)[##]	1.74 (1.05-2.88)*	1.59 (0,93-2,72)
Heat		
Occupation (technician)[#]	2.36 (1.42-3.92)**	1.83 (1.08-3.13)*
Phase of wind farm (under construction)[##]	1.34 (0.81-2.24)	1.02 (0.59-1.75)
Frequent changes between heat and cold		
Occupation (technician)[#]	1.42 (0.91-2.23)	1.36 (0.84-2.21)
Phase of wind farm (under construction)[##]	1.16 (0.72-1.85)	1.09 (0.66-1.79)
Odours		
Occupation (Technician)[#]	1.28 (0.82-2.01)	1.18 (0.73-1.92)
Phase of wind farm (under construction)[##]	1.09 (0.68-1.76)	1.00 (0.61-1.65)
Contact with chemicals or hazardous substances		
Occupation (technician)[#]	1.90 (1.21-2.99)**	1.76 (1.09-2.84)*
Phase of wind farm (under construction)[##]	0.82 (0.51-1.30)	0.79 (0.48-1.29)

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Lifting/carrying heavy loads		
Occupation (technician)#	2.99 (1.53-3.78)***	2.58 (1.58-4,23)***
Phase of wind farm (under construction)##	1.70 (1.05-2.73)*	1.47 (0.89-2.43)
Transport of aids (e. g. PPE, tools) over long distances		
Occupation (technician)#	2.40 (1.53-3.78)***	2.06 (1.27-3.33)**
Phase of wind farm (under construction)##	1.25 (0.78-1.98)	0.99 (0.61-1.62)
Working with twisted upper body/forward flexion of the spine		
Occupation (technician)#	3.42 (2.14-5.48)***	2.85 (1.74-4.69)***
Phase of wind farm (under construction)##	1.50 (0.94-2.41)	1.32 (0.80-2.19)
Working with unsupported raised arms (overhead work)		
Occupation (technician)#	3.37 (2.10-5.43)***	2.77 (1.67-4.58)***
Phase of wind farm (under construction)##	1.38 (0.86-2.22)	1.13 (0.68-1.87)
Reduced visibility		
Occupation (technician)#	1.43 (0.91-2.25)	1.21 (0.74-1.96)
Phase of wind farm (under construction)##	2.18 (1.34-3.53)**	1.74 (1.05-2.89)*
Closed/cramped quarters		
Occupation (technician)#	2.14 (1.35-4.51)**	1.79 (1.10-2.93)*
Phase of wind farm (under construction)##	1.71 (1.06-2.75)*	1.48 (0.89-2-44)
Climbing		
Occupation (technician)#	2.83 (1.71-4.51)***	2.30 (1.40-3.77)**
Phase of wind farm (under construction)##	2.08 (1.29-3.37)**	1.74 (1.05-2.89)*
Poor air quality/air conditioning		
Occupation technician)#	1.03 (0.66-1.61)	1.00 (0.62-1.60)
Phase of wind farm (under construction)##	0.61 (0.38-0.98)*	0.58 (0.35-0.95)*
Restricted movement		
Occupation (technician)#	0.94 (0.60-1.46)	0.70 (0.43-1.13)

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Phase of wind farm (under construction)[##]	1.18 (0.74-1.88)	0.99 (0.60-1.61)
Unpredictable waiting times (e.g. during "weather days")		
Occupation (technician)[#]	1.17 (0.74-1.85)	0.79 (0.48-1.31)
Phase of wind farm (under construction)[##]	2.08 (1.27-3.39)**	1.64 (0.97-2.76)

[#]reference: any other occupation; [##]reference: wind farm in operation
*p<0.05; **p<0.01; ***p<0.001
[a] Adjusted for age, nationality, offshore experience, work schedule and type of shift.

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Figure Legends

Figure 1. Study flow.

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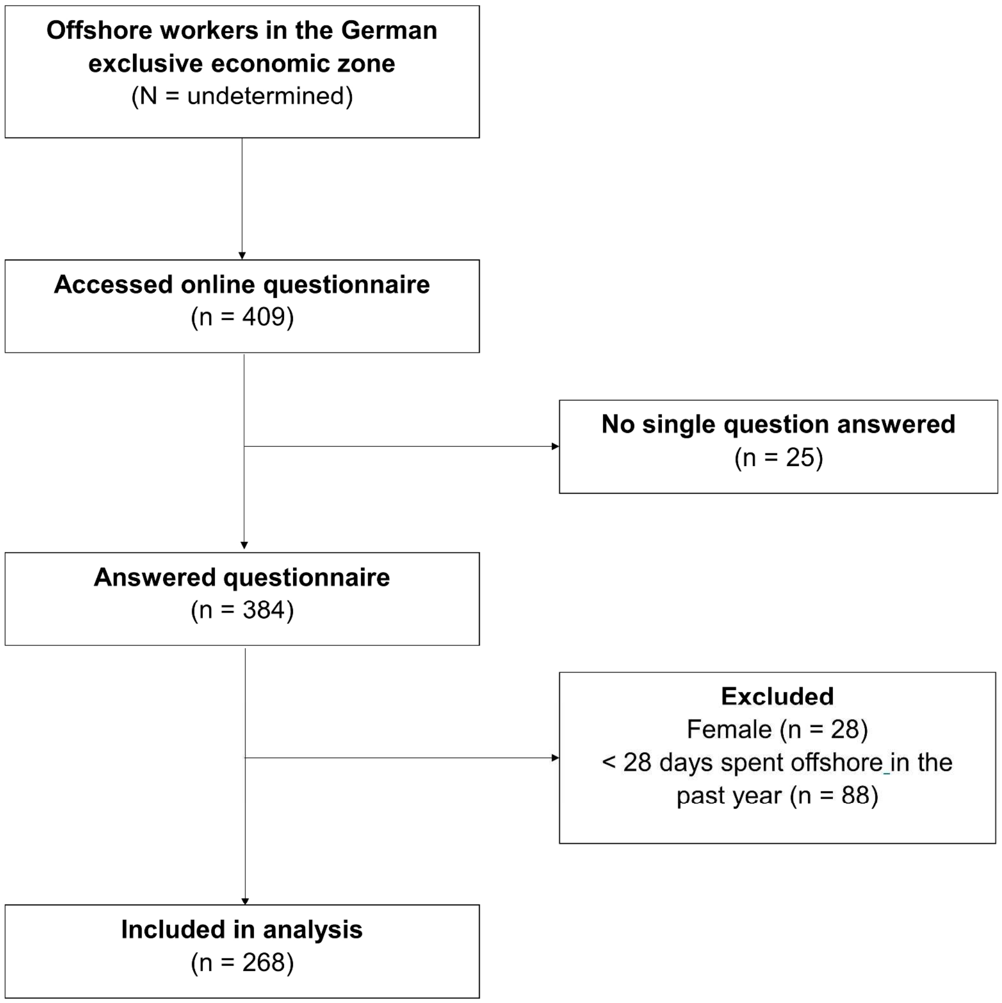

Figure 1. Study flow

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Additional Tables

Table A1. Physical strains by occupation.

	Always		Often		Sometimes		Rarely		Never / hardly ever	
	n	%	n	%	n	%	n	%	n	%
Noise (n=252)										
Technicians	22	17.6	55	44.0	43	34.4	4	3.2	1	0.8
Other	13	10.2	50	39.4	44	34.6	17	13.4	3	2.4
Vibrations/oscillation (n=255)										
Technicians	21	16.7	54	42.9	32	25.4	16	12.7	3	2.4
Other	18	14.0	40	31.0	37	28.7	21	16.3	13	10.1
Humidity/moisture (n=254)										
Technicians	3	2.4	49	38.9	60	47.6	12	9.5	2	1.6
Other	3	2.3	35	27.3	59	46.1	24	18.8	7	5.5
Cold (n=254)										
Technicians	1	0.8	41	32.5	75	59.5	8	6.3	1	0.8
Other	2	1.6	32	25.0	70	54.7	17	13.3	7	5.5
Heat (n=254)										
Technicians	2	1.6	36	28.8	73	58.4	13	10.4	1	0.8
Other	1	0.8	19	14.7	80	62.0	24	18.6	5	3.9
Frequent changes between heat and cold (n=252)										
Technicians	5	4.0	24	19.4	51	41.1	37	29.8	7	5.6
Other	3	2.3	24	18.8	43	33.6	44	34.4	14	10.9
Odors (n=252)										
Technicians	3	2.4	21	17.1	47	38.2	42	34.1	10	8.1
Other	4	3.1	20	15.5	41	31.8	48	37.2	16	12.4
Contact with chemicals or hazardous substances (n=252)										
Technicians	4	3.3	36	29.3	42	34.1	31	25.2	10	8.1
Other	4	3.1	21	16.3	41	31.8	45	34.9	18	14.0
Lifting / carrying heavy loads (n=253)										
Technicians	9	7.2	58	46.4	44	35.2	12	9.6	2	1.6

Other	7	5.5	32	25.0	42	32.8	39	30.5	8	6.3
Transport of aids (e. g. PPE, tools) over long distances (n=253)										
Technicians	30	24.0	44	35.2	28	22.4	20	16.0	3	2.4
Other	14	10.9	32	25.0	45	35.2	23	18.0	14	10.9
Working with twisted upper body/forward flexion of the spine (n=254)										
Technicians	5	4.0	57	45.6	42	33.6	18	14.4	3	2.4
Other	4	3.1	25	19.4	47	36.4	33	25.6	20	15.5
Working with unsupported raised arms (overhead work) (n=254)										
Technicians	1	0.8	30	24.0	61	48.8	29	23.2	4	3.2
Other	0	0.0	14	10.9	46	35.7	41	31.8	28	21.7
Reduced visibility (n=252)										
Technicians	0	0.0	17	13.8	55	44.7	39	31.7	12	9.8
Other	0	0.0	21	16.3	40	31.0	44	34.1	24	18.6
Closed/cramped quarters (n=253)										
Technicians	10	8.0	44	35.2	52	41.6	14	11.2	5	4.0
Other	4	3.1	36	28.1	43	33.6	33	25.8	12	9.4
Climbing (n=254)										
Technicians	34	27.2	61	48.8	23	18.4	6	4.8	1	0.8
Other	20	15.5	47	36.4	29	22.5	20	15.5	13	10.1
Poor air quality / air conditioning (n=253)										
Technicians	13	10.4	39	31.2	30	24.0	36	28.8	7	5.6
Other	17	13.3	29	22.7	42	32.8	30	23.4	10	7.8
Restricted movement (n=254)										
Technicians	4	3.2	31	24.8	44	35.2	33	26.4	13	10.4
Other	7	5.4	34	26.4	42	32.6	27	20.9	19	14.7
Unpredictable waiting times (e.g. during "weather days") (n=254)										
Technicians	4	3.2	46	36.8	54	43.2	20	16.0	1	0.8
Other	2	1.6	46	35.7	57	44.2	19	14.7	5	3.9

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Table A2. Physical strains by phase of the wind farm.

	Always		Often		Sometimes		Rarely		Never / hardly ever	
	n	%	n	%	n	%	n	%	n	%
Noise (n=251)										
Under construction	11	12.4	46	51.7	28	31.5	3	3.4	1	1.1
In operation	24	14.8	58	35.8	59	36.4	18	11.1	3	1.9
Vibrations/oscillation (n=254)										
Under construction	14	15.6	39	43.3	25	27.8	9	10.0	3	3.3
Other	25	15.2	55	33.5	44	26.8	27	16.5	13	7.9
Humidity/moisture (n=253)										
Under construction	3	3.3	43	47.8	34	37.8	9	10.0	1	1.1
In operation	3	1.8	41	25.2	84	51.5	27	16.6	8	4.9
Cold (n=253)										
Under construction	2	2.2	30	33.3	52	57.8	4	4.4	2	2.2
In operation	1	0.6	43	26.4	92	56.4	21	12.9	6	3.7
Heat (n=253)										
Under construction	3	3.3	21	23.3	52	57.8	13	14.4	1	1.1
In operation	0	0.0	34	20.9	100	61.3	24	14.7	5	3.1
Frequent changes between heat and cold (n=251)										
Under construction	2	2.2	19	21.3	34	38.2	28	31.5	6	6.7
In operation	6	3.7	29	17.9	59	36.4	53	32.7	15	9.3
Odors (n=251)										
Under construction	2	2.2	13	14.6	37	41.6	28	31.5	9	10.1
In operation	5	3.1	28	17.3	51	31.5	61	37.7	17	10.5
Contact with chemicals or hazardous substances (n=251)										
Under construction	3	3.4	16	18.0	32	36.0	27	30.3	11	12.4
In operation	5	3.1	41	25.3	51	31.5	48	29.6	17	10.5
Lifting / carrying heavy loads (n=252)										
Under construction	8	9.0	39	43.8	23	25.8	15	16.9	4	4.5
In operation	8	4.9	51	31.3	62	38.0	36	22.1	6	3.7
Transport of aids (e. g. PPE, tools) over long distances (n=252)										

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Under construction	17	19.3	28	31.8	24	27.3	15	17.0	4	4.5
In operation	27	16.5	48	29.3	48	29.3	28	17.1	13	7.9
Working with twisted upper body/forward flexion of the spine (n=253)										
Under construction	3	3.4	37	41.6	25	28.1	18	20.2	6	6.7
In operation	6	3.7	45	27.4	63	38.4	33	20.1	17	10.4
Working with unsupported raised arms (overhead work) (n=253)										
Under construction	1	1.1	19	21.3	35	39.3	27	30.3	7	7.9
In operation	0	0.0	25	15.2	71	43.3	43	26.2	25	15.2
Reduced visibility (n=251)										
Under construction	0	0.0	17	19.3	41	46.6	24	27.3	6	6.8
In operation	0	0.0	21	12.9	53	32.5	59	36.2	30	18.4
Closed/cramped quarters (n=252)										
Under construction	6	6.7	35	39.3	29	32.6	19	21.3	0	0.0
In operation	8	4.9	45	27.6	65	39.9	28	17.2	17	10.4
Climbing (n=253)										
Under construction	25	28.1	41	46.1	16	18.0	5	5.6	2	2.2
In operation	28	17.1	67	40.9	36	22.0	21	12.8	112	7.3
Poor air quality / air conditioning (n=252)										
Under construction	6	6.8	22	25.0	25	28.4	28	31.8	7	8.0
In operation	24	14.6	46	28.0	46	28.0	38	23.2	10	6.1
Restricted movement (n=253)										
Under construction	2	2.2	26	29.2	31	34.8	23	25.8	7	7.9
In operation	9	5.5	39	23.8	54	32.9	37	22.6	25	15.2
Unpredictable waiting times (e.g. during "weather days") (n=253)										
Under construction	2	2.2	41	46.1	39	43.8	6	6.7	1	1.1
In operation	4	2.4	51	31.1	71	43.3	33	20.1	5	3.0

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Supplemental Material to Velasco-Garrido et al. A cross-sectional survey of physical strains among offshore wind farm workers in the German exclusive economic zone.

Project "BestOff"
Subproject "Physical demands and psychological strains in the offshore wind industry"

Questionnaire

About you.
To begin, we require some personal information.

1. Sex
☐ male
☐ female

2. How old are you? (in years)

19 or younger	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 and older
☐	☐	☐	☐	☐	☐	☐	☐	☐

3. Which is your nationality? (If you have more than one, please write only one)

[ ]

4. Which of the following best describes your family status?
☐ single
☐ in a relationship – living in a shared household
☐ in a relationship – living in separate households

5. Are children less than 18 years of age living in your household?
☐ yes
☐ no

Your offshore occupation.
The following questions refer to your <u>current</u> offshore occupation. If you have not worked offshore recently, then please refer to your <u>last</u> offshore occupation.

6. How long have you been working in the offshore wind industry?
☐ less than 1 year
☐ 1 – 3 years
☐ more than 3 years

7 How long ago was your last offshore assignment?
☐ I am currently offshore
☐ less than 1 month
☐ 1 – 3 months
☐ 4 – 6 months
☐ 7 – 12 months
☐ more than 12 months

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8. Which of the following best describes your offshore occupation?
☐ management onshore (back office)
☐ supervisor (offshore in executive position, e. g. side manager, platform master, ...)
☐ technician / maintenance
☐ catering / room service
☐ ship's crew member
☐ research personnel / surveyor
☐ medical / paramedical personnel
☐ other (please specify)

9. Which of the following best describes your current employment status?
☐ employed by an operator company
☐ employed by a sub-contractor
☐ temporary agency worker
☐ self-employed / freelancer

10. In which phase is the offshore windpark on which you are currently working?
☐ in construction
☐ in operation

11. Do you have a regular offshore schedule (e.g. every 14 days)?
☐ 7 days offshore – 7 days onshore
☐ 14 days offshore – 14 days onshore (or 15 days offshore – 13 days onshore)
☐ 21 days offshore – 21 days onshore
☐ no regular schedule, only occasional assignments
☐ other regular schedule (please specify)

12. How long have you been working on this schedule?
☐ less than 2 months
☐ 2 – 6 months
☐ 7 – 12 months
☐ more than 12 months

13. In the last year, how often did you work offshore?
☐ not at all
☐ 1 – 5 times
☐ 6 – 10 times
☐ more than 10 times

14. In the last year, approximately how many days in total did you work offshore?

15. What kind of shifts do you work offshore?
☐ only day shifts
☐ only night shifts
☐ rotating (day / night)

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16. Where do you live during your offshore assignments?

☐ offshore – on a platform (accommodation platform / substation platform / converter platform)
☐ offshore – on a construction ship (e. g. jack up vessel)
☐ offshore on a hotel ship
☐ offshore – in a container on a platform
☐ on an island – at a hotel or flat
☐ on the mainland – at a hotel or flat

17. In what kind of cabin / room do you live during your offshore assignments?

☐ single cabin / room
☐ double cabin / room

18. <u>Before</u> working in the offshore wind industry, had you already taken on work assignments that involved long periods of absence from your home?

☐ yes
☐ no

19. What mode of transportation do you <u>usually</u> take between your offshore accommodation and your offshore workplace?

☐ ship / boat
☐ helicopter
☐ both
☐ no transfer needed, accommodation and workplace are at the same location

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Supplemental Material to Velasco-Garrido et al. A cross-sectional survey of physical strains among offshore wind farm workers in the German exclusive economic zone.

Working conditions offshore.
The following questions refer to your working conditions offshore.

Examples of different stressors typical for the offshore workplace are listed below. Please indicate how often you are exposed to each of them. (Please give one answer per item)

	always	often	sometimes	rarely	never / hardly ever
noise	☐	☐	☐	☐	☐
vibrations / oscillation	☐	☐	☐	☐	☐
humidity / moisture	☐	☐	☐	☐	☐
cold	☐	☐	☐	☐	☐
heat	☐	☐	☐	☐	☐
frequent changes between heat and cold	☐	☐	☐	☐	☐
odours	☐	☐	☐	☐	☐
contact with chemicals or hazardous substances	☐	☐	☐	☐	☐
lifting / carrying heavy loads	☐	☐	☐	☐	☐
transport of aids (e. g. PPE, tools) over long distances	☐	☐	☐	☐	☐
working with twisted upper body / forward flexion of the spine	☐	☐	☐	☐	☐
working with unsupported raised arms (overhead work)	☐	☐	☐	☐	☐
reduced visibility	☐	☐	☐	☐	☐
closed / cramped quarters	☐	☐	☐	☐	☐
climbing	☐	☐	☐	☐	☐
poor air quality / air conditioning	☐	☐	☐	☐	☐
restricted movement	☐	☐	☐	☐	☐
unpredictable waiting times (e.g. during "weather days")	☐	☐	☐	☐	☐

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	**Item #**	**Recommendation**	**Reported on page #**
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	1,7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8,9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8,9
Bias	9	Describe any efforts to address potential sources of bias	*9,16*
Study size	10	Explain how the study size was arrived at	7 Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8,9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n.a.
		(*e*) Describe any sensitivity analyses	n.a.
Results			

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Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	All tables and figures
Outcome data	15*	Report numbers of outcome events or summary measures	11,12, tables 1,2,3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11,12, tables 2 and 3
		(*b*) Report category boundaries when continuous variables were categorized	n.a.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n.a.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n.a.
Discussion			
Key results	18	Summarise key results with reference to study objectives	13,14,15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16,17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-19
Generalisability	21	Discuss the generalisability (external validity) of the study results	16-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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