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Effects of Shift and Night Work in the Offshore Petroleum Industry: A Systematic Review

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Abstract: Shift and night work are associated with several negative outcomes. The aim of this study was to make a systematic review of all studies which examine effects of shift and night work in the offshore petroleum industry, to synthesize the knowledge of how shift work offshore may affect the workers. Searches for studies concerning effects on health, sleep, adaptation, safety, working conditions, family- and social life and turnover were conducted via the databases Web of Knowledge, PsycINFO and PubMed. Search was also conducted through inspection of reference lists of relevant literature. We identified studies describing effects of shift work in terms of sleep, adaptation and re-adaptation of circadian rhythms, health outcomes, safety and accidents, family and social life, and work perceptions. Twenty-nine studies were included. In conclusion, the longitudinal studies were generally consistent in showing that adaptation to night work was complete within one to two weeks of work, while re-adaptation to a daytime schedule was slower. Shift workers reported more sleep problems than day workers. The data regarding mental and physical health, family and social life, and accidents yielded inconsistent results, and were insufficient as a base for drawing general conclusions. More research in the field is warranted.

Key words: Accidents, Adaptation, Health, Shift work, sleep, Night work, Offshore, Petroleum industry

Introduction

Shift work is commonly defined as work that occurs between 1900 and 0600 hours[1)]. Night work involves a type of shift work where the majority of the work takes place between 2200 and 0600 hours[2)]. Studies show that shift work has increased during the past decades, due among other things to the industry's demand for continuous production[3)].

Shift work and night work are associated with a range of negative outcomes. The most common health-related effect of shift work is disturbed sleep, such as difficulty falling asleep, and shortened sleep duration[4)]. Shift work is also associated with increased fatigue[4)]. Shift work may lead to shift work disorder (SWD) which in the second edition of the International Classification of Sleep Disorders[5)] is recognized as a circadian rhythm sleep disorder characterized by symptoms such as excessive sleepiness and insomnia[6)]. The prevalence of SWD varies across different studies, from 10%[7)] to 38%[8)]. The findings from a review conducted in 2008 indicated that less than 3% of permanent night workers show complete adaptation of their melatonin rhythm to night work[9)]. Shift and night work have also been shown to significantly increase the risk for work-related accidents[10)].

Several other health issues are also related to shift work[4)].

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A meta-analysis demonstrated that shift work increased the risk for cardiovascular disease by 40%[11], and in a recent review, the authors concluded that shift workers appear to have increased risk of gastrointestinal symptoms, along with increased risk of peptic ulcer disease[12]. A consistent finding is that prolonged night work is associated with an increased risk of breast cancer among women[13, 14]. Studies have further indicated an association between shift work and metabolic disturbances[15–17], and shift work is also found to be a risk factor for poor mental health[18, 19]. Shift work may also be detrimental for reproductive health, in terms of prolonged waiting time to pregnancy, low birth weight, increased risk for preterm delivery and increased risk for spontaneous abortions[20, 21]. Shift work may also pose an increased risk for work-family conflicts[22].

The offshore petroleum industry is characterized by an exceptionally high prevalence of shift work. A recent survey showed that approximately 55% of offshore workers in the Norwegian petroleum sector sometimes or regularly work night shifts[23]. The standard offshore shift duration is 12 hours[24], which is considerably longer than regular shifts onshore. Further, the offshore petroleum industry operates a number of different work schedules, with variations in duration of work and onshore leave periods[25]. While the most frequent arrangement in the UK petroleum offshore industry consists of two weeks of work offshore followed by two weeks at home[26], most shift workers in the Norwegian sector follow a schedule consisting of two weeks of work offshore and four weeks off[6]. The most common alternatives for shift rotation schedules are fixed shifts of 14 consecutive day shifts (14D) or 14 consecutive night shifts (14N) alternating on tours, or swing shifts comprising one week of night shifts (normally the first one) and one week of day shifts within the same work period (7N/7D)[27]. The offshore industry further differs from the onshore sector as the former environment may be better adapted to 24 hour operations[28]. Several factors influencing diurnal rhythms onshore, such as domestic duties and light exposure differ significantly in the isolated work environment offshore[29]. While offshore, the workers are isolated from family, relatives and friends; and have no commitments to daily family life or other onshore obligations[29, 30]. The offshore period involves long working hours, for most workers indoors, with little exposure to sunlight[29]. Strict medical standards and safety courses are required to work offshore, and medical examinations given before recruitment and at regular intervals thereafter ensure that the personnel are physically and mentally fit for the harsh demands of the working environment[31, 32].

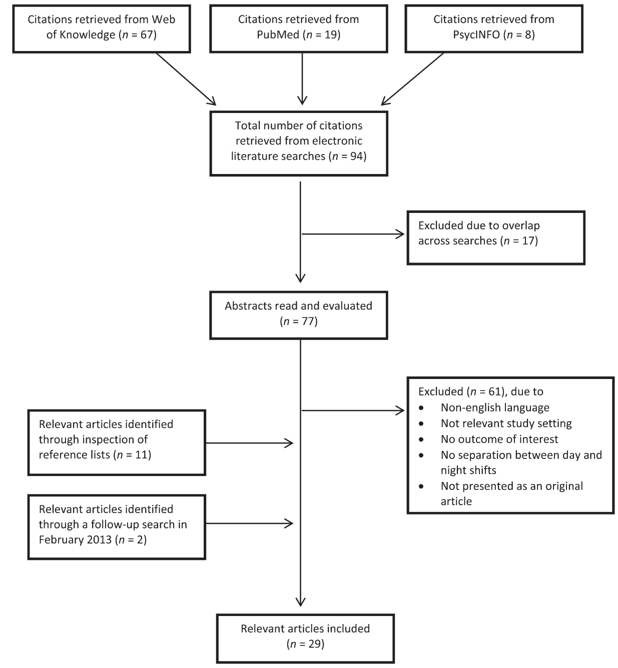

Fig. 1. Literature search and selection.

Hence, offshore personnel represent a selected group of particularly healthy and robust workers[27, 31].

The different working conditions and shift work schedules make it difficult to generalize findings regarding effects of shift work onshore, where most of the shift work research has been conducted, to the offshore petroleum industry. Against this backdrop, we decided to conduct a systematic review of all studies concerning effects of shift work and night work in the offshore petroleum industry on health, sleep, adaptation, safety, working conditions, family- and social life, and turnover, in order to make a synthesis of the knowledge of how shift work offshore may affect the workers.

Methods

A literature search was conducted during June 2012 by use of the literature bases Web of Knowledge, PsycINFO and PubMed (Fig. 1). Key words that were used included “shiftwork*” or “shift work*” or “nightwork*” or “night work*” combined with “offshore” or “off shore” and “oil*” or “petroleum”. No year restrictions were used. In total, the searches resulted in 77 hits. In addition, relevant studies were identified by inspection of reference lists of central publications. Studies had to fulfill the following inclusion criteria in order to be included in the present review: 1) The publication was written in English; 2) The study was conducted on subjects working shifts in the offshore petroleum industry, thus studies concerning e.g. offshore shipping or fleet vessels were excluded; 3) The study concerned consequences of working shift or night, and included relevant outcome data in terms of health, sleep, adaptation, re-adaptation, work-family spillover, working conditions, accidents, safety and turnover; 4) The study separated between day and night shifts; 5) The study was presented as an original article, and published in a peer-reviewed journal. A total of 29 studies were identified satisfying the inclusion criteria.

In the present review, we differentiated between longitudinal and cross-sectional studies. Studies that included two or more measurement points were defined as longitudinal, whereas cross-sectional studies employed only one measurement point for each participant. Some of the studies classified as longitudinal also included cross-sectional findings.

Results

A total of 29 studies were included in this review; 13 examined outcome data of circadian adaptation and 11 concerned sleep. Eight studies dealt with shift work and mental or physical health, while two studies focused on family-work relations. Seven studies addressed safety/accidents directly, or included reaction time test assessments relevant for safety. One study concerned work perceptions, and one study addressed perceived mastery of work. Of the 29 studies, 27 were conducted in the Norwegian or in the UK offshore sector, of which 24 were from the North Sea. Two studies stemmed from the Campos Basin in Brazil. All studies reviewed had samples consisting of mostly or exclusively males. The average age in the different samples ranged between 33 and 49 years. The oldest study was published in 1990; the latest in 2012. Table 1 shows the results from the 14 cross-sectional studies included, and data from the 15 longitudinal studies that satisfied the inclusion criteria are presented in Table 2.

Shift work and sleep

In total, 11 studies concerning shift work and its association with sleep and sleepiness were identified. Eight of these studies were cross-sectional, three were longitudinal. Five cross-sectional studies compared offshore day workers with offshore shift/night workers. Two studies showed that the shift/night workers reported more sleep problems than day workers[28, 33]. In another study, permanent day workers reported better sleep quality than all other shift schedules[31]. However, in that study the relationship between shift schedules and sleep quality disappeared when controlling for risk perception and safety climate. The findings from yet another study indicated that shift/night work, compared to day work, was associated with longer sleep duration[34]. A separate study demonstrated that offshore workers reported poor sleep quality during the first and the last days at home, independent of shift pattern at work[35].

Three of the cross-sectional studies regarding sleep and sleepiness compared offshore workers with onshore workers across different shift patterns. One study found that in both groups, sleep quality was best during the off work period as compared to day work and night work[36]. Further, offshore workers reported better sleep quality during night work than day work, while onshore workers reported the opposite. In the same study, offshore workers reported longer sleep duration during night work and lower sleep quality during day work than onshore workers[36]. In another study, offshore workers reported better sleep quality and longer sleep duration than the onshore workers[37]. In both groups, the reported sleep duration and sleep quality were highest during the off work period, intermediate during day work and lowest during night work[37]. In the only study investigating the prevalence of SWD, 23.3% of swing shift oil rig workers fulfilled the criteria for the disorder[6]. These workers, as compared to non-SWD workers, reported lower sleep quality, more subjective health complaints and poorer coping. However, in this study the reports of shift workers without SWD were no different from the reports of day workers regarding sleep and sleepiness.

One longitudinal study assessed sleep during different shift schedules in offshore workers. The findings showed that sleep efficiency was higher during day shift compared to night shift and swing shift; sleep duration was shorter during swing shift than during night shift and day shift, and sleep quality was better during swing shift than during night shift and day shift for the first week of work[38]. Another longitudinal study (based on the same sample) examined sleepiness across the same three shift schedules. Subjective sleepiness was highest in the beginning of night and swing shifts[39]. During night shift it gradually decreased, while during swing shift there was an initial decrease until a new peak in sleepiness appeared right after swinging from night to day work in the middle of the work period. Sleepiness at home was higher following night shift compared to following swing shift. Further, one longitudinal study found that both day workers and swing shift workers (7N/7D) reported poorer sleep quality and more insomnia symptoms at the end of a two week work period than at the start[40]. Further, at the end of the work period, there was a higher proportion of insomniacs among swing shift workers than among day workers.

In sum, the findings concerning sleep quality and sleep duration are somewhat inconsistent regarding whether day or night workers are better off[28, 31, 34, 36, 37]. The majority of studies found that offshore day shift workers reported better sleep quality, longer sleep duration and fewer sleep problems such as difficulty falling and staying asleep, and fragmented sleep, than offshore night shift workers[28, 31, 33, 37].

Shift work, adaptation and re-adaptation

A total of 13 studies concerning adaptation and re-adaptation, all longitudinal, were identified.

Adaptation

Five studies assessed circadian adaptation to night work by measuring the urinary 6-sulphatoxymelatonin acrophase (aMT6s). In three of these studies, the majority of or all workers were fully adapted to night work within a week, by phase delay[41–43]. One study found that most subjects (14 of 16) were adapted to night work by the final days of a two or three week night shift[24]. In a study with two study groups, subjects studied in March adapted to night work within a week by phase advance[44]. Subjects in the other group, assessed in November, showed no acrophase adaptation.

One study assessing circadian adaptation to night shift using cortisol measurement demonstrated that regardless of shift schedule (14N or 7N/7D), cortisol adaptation to night work was complete within a week[29].

Four studies assessed adaptation by means of sleep and sleepiness questionnaires/diaries and actigraphy recordings. Two studies showed that adaptation was complete within a few days, indicated by rapid reduction in sleepiness during work hours[39, 45]. In another study, measures of sleepiness and sleep gradually improved during night shift, and the workers reported that adaptation was complete within a few days[46]. One study found that in terms of sleep measured by sleep diary and actigraphy recordings, adaptation to swing shift seemed more difficult than adaptation to day shift and/or night shift[38].

Overall, the main findings regarding adaptation of circadian rhythms show that most workers were fully adapted to night work within one[29, 39, 41–43, 45, 46] to two or three weeks[24].

Re-adaptation

Ten studies assessed re-adaptation from night work back to a daytime schedule at work or at home. Three studies assessed re-adaptation by objective methods, using aMT6s acrophase or cortisol rhythm. In one of these studies, six of the 19 subjects who adapted to night work, phase advanced when swinging from night work to day work, and these six subjects were fully re-adapted within a week[43]. The remaining subjects in this study did not achieve re-adaptation; seven showed little phase change while six continued to phase delay. A comparable study also found large individual variations during re-adaptation; as a group they did not adapt back to a day-night rhythm, with some subjects showing phase delay, others phase advance, and many showing only small phase changes[42]. In a study measuring cortisol rhythm, the rhythms were not readapted to a day schedule one week after returning home from two weeks of night work[29]. Following swing shift, however, the cortisol rhythms were readapted after one week at home[29].

By use of a sleep diary and questionnaire, one study found that re-adaptation was slower and more difficult than adaptation to night shift; subjective sleepiness was higher during the first re-adaptation week at home than during the first week of night work[45]. Another study found that sleepiness increased during re-adaptation following night shifts, as compared to following day or swing shifts[39]. In another study, subjects reported that re-adaptation back to daytime work was slower than the preceding adaptation to night work[46]. A different study using a sleep diary and actigraphy recordings demonstrated that there were no differences in re-adaptation to a daytime schedule at home across different shift schedules in terms of sleep[38].

In sum, several studies included in this review showed that re-adaptation from night work back to a daytime schedule offshore or at home was slower than adaptation to night work[29, 42, 45].

Three offshore intervention studies regarding sleep, adaptation and re-adaptation have been conducted. Two placebo-controlled intervention studies demonstrated that bright light treatment had a positive effect on adaptation to night work and on re-adaptation back to a daytime schedule, as measured by subjective sleep and sleepiness ratings[47, 48]. The light treatment was especially effective during re-adaptation[47]. In another intervention study where the subjects received light treatment and wore sunglasses at appropriate times, objective sleep duration and sleep efficiency were improved after treatment[49]. However, subjective data in this study showed decreased sleep quality during light treatment. Also, measures of

Table 1. Summary of cross-sectional studies

Authors/ date	Study method	Sample	Research topic	Measures	Main results
Parkes (1999)[33]	Questionnaire administered once. Day work compared with rotating day/night shift work. Duration of work period two-three weeks, 12 h shifts.	1320 North Sea oil and gas industry personnel, 680 day workers, 640 shift workers. Mean age 38.9 yr. Average response rate across 17 installations of 83% (UK).	Health, sleep, injuries. How offshore shift work predicts sleep and health outcomes, controlling for individual differences, job type and work perceptions.	Psychosomatic complaints (headaches, musculoskeletal pain, gastric problems and sleep problems), affective distress and work-related injuries.	Shift workers reported more sleep problems, gastric problems, psychological distress and work-related injuries than day workers. Controlled for job type and demographic variables, shift work predicted gastric problems and sleep complaints. With no control for job type, shift work also predicted mental health and injuries. Rotating day/night shift workers had lower BMI than day workers.
Menezes *et al*. (2004)[28]	Questionnaire administered once. Comparison of fixed daytime workers and shift/night workers. 81% worked for two weeks with a midtour change. Usually 12 h shifts.	Offshore oil and gas installation personnel in the Campos Basin, Brazil. 86 day workers, 80 males, 6 females, mean age 35.8 yr. 93 shift/night workers, 91 males, 2 females, mean age 37.7 yr. Response rate 58% (Brazil).	Sleep in offshore workers.	Sleep parameters (sleep quality, sleep symptoms, sleep duration etc.).	The shift/night group more often reported poor sleep quality, difficulties in falling and staying asleep, long sleep onset latency, short sleep duration, irregular bed times and feeling tired upon awakening.
Hope *et al*. (2010)[31]	Questionnaire administered once. Comparison of five shift patterns; permanent days or nights, fixed shifts, swing shifts (7N/7D, 7D/7N) and "varying shift".	9,601 offshore workers in the North Sea, 90% males, 10% females; most predominantly between the ages of 31 and 50. Response rate across 52 installations of 50% (Norway).	Relationship between risk perception, safety climate and sleep quality.	Sleep quality, risk perception, and safety climate.	Permanent day shift workers reported better sleep quality than all other shift arrangements, but with small effect sizes. Shift patterns only predicted sleep quality in univariate analysis, but not in the multivariate model where risk perception and safety climate were included.
Waage *et al*. (2010)[34]	Questionnaire distributed during the first work day in day workers (14D) and swing shift workers (7N/7D), 12 h shifts during two weeks of work.	204 oil rig shift workers in the North Sea. 7 females, 197 males; mean age 42.9 yr. 103 swing shift workers, 96 day workers. Response rate 79% (Norway).	Sleep and health during offshore work.	Sleep parameters, circadian preference and subjective health complaints.	Swing shift was associated with longer sleep duration, compared to day shift. For swing shift workers, sleep duration was negatively associated with age. Shift type, age and shift work exposure time seemed not to affect shift work tolerance.
Rodrigues *et al*. (2001)[35]	Interviews of offshore shift workers (rotating, on call, fixed days + call outs, fixed day, evenings + nights, and fixed nights) and data from work accident registry were included. Mainly 12 h shifts were worked.	51 male offshore shift workers in the Campos Basin, Brazil, mean age 37.6 yr (Brazil).	Offshore shift work impacts on social and family life, accidents, sleep quality.	Sleep quality, shift work impact on social and family life, accidents.	Offshore shift workers reported difficulties in reconciling offshore work with family life, as well as poor sleep the first and last days during work off period independent of shift type. The relative risk of accidents was 51% higher between 1801 and 0559 hours, compared to between 0600 and 1800 hours.
Parkes (1994)[36]	Questionnaire administered once. Comparison of offshore and onshore workers across night work, day work and off work period. Duration of work period offshore was two weeks with 12 h shifts.	Male oil industry personnel from three oil platforms in the North Sea. 84 offshore workers, mean age 40.9 yr and 88 onshore workers, mean age 44.5 yr. Response rate > 90% (UK). Sample as for Parkes (1992).	Sleep patterns across day shift, night shift and during off work period.	Self-reported sleep duration and sleep quality during different shifts schedules (day work, night work, off work period).	Offshore workers reported longer night work sleep duration and lower day work sleep quality compared to those onshore. In both groups, sleep quality was best during off work period. For the offshore group night work sleep quality was higher than day work sleep quality, while the opposite was found for onshore workers. For onshore workers day work sleep duration was longer than night work sleep duration.
Parkes (2002)[37]	Questionnaire administered once. Two weeks of 12 h shifts, fixed shifts (14D,14N) or swing shift (7D/7N, 7N/7D) offshore. Workers with fast, intermediate or weekly rotations onshore.	456 male offshore personnel from 11 platforms in the North Sea, mean age 38.4 yr and 330 male onshore workers, mean age 42.6 yr (UK).	Sleep pattern across day shift, night shift and during off work.	Self-reported sleep duration and sleep quality for three different shifts.	Offshore workers reported better sleep quality and longer sleep duration than onshore workers. For both offshore and onshore workers: sleep duration off work > day work > night work, and sleep quality off work > day work > night work.

Table 1. continued

Authors/ date	Study method	Sample	Research topic	Measures	Main results
Waage *et al*. (2009)[6]	Questionnaire administered during the first day of a two week working period reflecting symptoms during the previous four week period off. Swing shift workers (7N/7D) were compared to day workers. Shift duration was 12 h.	103 oil rig swing shift workers, mean age 39.8 yr, 98 males, 5 females. 96 day workers, no information about gender and age. North Sea. Response rate 78.8% (Norway).	Shift work disorder (SWD) in offshore workers.	Questionnaires about SWD, sleep, sleepiness, insomnia, circadian preference, subjective health complaints, psychological demands and job control.	SWD prevalence was 23.3%. Individuals with SWD reported poorer sleep quality, more subjective health complaints and poorer coping during the four-weeks on leave compared to those without SWD. Shift workers without SWD were comparable to day workers on all parameters but one; day workers reported higher degree of job control.
Parkes (1992)[32]	Questionnaire administered once. Comparison of swing shift workers (7N/7D) offshore and onshore workers with rapid rotation across night shift, day shift and off work period. Work period offshore lasted for two weeks with 12 h shifts.	Male oil industry personnel in the North Sea. 84 offshore workers, mean age 40.9 yr and 88 onshore workers, mean age 44.5 yr. Response rate > 90%. Sample as for Parkes (1994) (UK).	Mental health among offshore workers.	Mental health and neuroticism, work condition measures.	Offshore swing shift workers had significantly higher anxiety scores. No group differences regarding somatic symptoms or social dysfunction.
Ljoså *et al*. (2011)[50]	Web-based questionnaire administered once. Comparison of day work and work involving night shifts. Shifts lasted 12 h for two weeks.	1,336 North Sea offshore shift workers, 83% male, 17% female. Mean age 45.1 yr. Shift schedule including night work: 680 subjects. Response rate 56%. Sample as for Ljoså *et al.* (2012) (Norway).	Mental health among offshore workers.	Mental distress.	Shift schedules were only univariately related to mental distress. Shift work arrangements lost their significance when adjusted for the individual factors of age, gender, marital status, and shift work locus of control.
Parkes (2002)[51]	Questionnaire administered once. Comparison of day work with rotating day/ night shift work offshore, typically 7N/7D. Work period of two weeks, 12 h shifts.	1,574 male offshore personnel in the North Sea, 787 day-night shift workers and 787 day workers. Mean age 38.7 yr. Average response rate across 17 installations: 82.9% (UK).	Health, BMI. Interactive effects of shift work patterns, age and years of shift work exposure on BMI.	Self-reported height and weight.	No main effect of shift pattern on BMI itself, but continued exposure to rotating shift work was related to increased BMI. Increase in BMI with age was significantly greater for rotating shift workers than for day workers.
Ljoså & Lau (2009)[52]	Web-based questionnaire administered once. Offshore: day work, fixed shifts (14D, 14N), swing shifts (7D/7N), and "other rotations". Onshore: all types of shifts.	1,697 onshore and offshore petroleum personnel in the Norwegian industry. 299 females, 1,398 males, most predominantly between the ages of 40 and 49. Response rate 55.9% (Norway).	Family and social life in relation to shift rotation patterns.	Measures of satisfaction with social and family life and coping strategies.	Generally low scores on questions concerning problems with social and family life caused by shift work. The majority of shift workers reported few problems with social and domestic/ family life, with onshore workers being worse off than offshore workers.
Parkes (2003)[30]	Questionnaire distributed once. Comparison of shift workers and day workers onshore and offshore. Offshore: 12 h shifts during two week word periods of fixed shifts (14D, 14N) or swing shifts (7D/7N, 7N/7D).	1,867 male oil industry personnel in the North Sea. 1,067 offshore workers and 800 onshore workers. Mean age for the whole sample was 41.1 yr. Mean response rate across 17 offshore installations 82.6%, onshore response rate on average 65% (UK).	Work perceptions among offshore and onshore workers.	Perceived work environment.	Offshore shift workers reported greater exposure to physical stressors than offshore day workers. The differences in work perceptions were generally more marked in the onshore setting, where shift workers perceived their environment less favorably than day workers.
Ljoså *et al.* (2012)[54]	Web-based questionnaire administered once. Comparison of day work and work involving night shifts during a two-week offshore work period, 12 h shifts.	1,336 offshore workers in the North Sea. 83% males, 17% females. Mean age 45.1 yr. Response rate 56%. Comparison sample: representative sample of Scandinavian workers (n=1,015). 63% males and 37% females. Sample as for Ljoså *et al.* (2011) (Norway).	Associations between individual and work-related factors and perceived mastery of work.	Perceived mastery of work, individual factors and work-related factors.	Night work was negatively related to perceived mastery of work in a bivariate analysis, but was unrelated to perceived mastery of work in a multivariate analysis. Offshore shift workers reported significantly higher levels of perceived mastery of work than the control group.

D = day (s); N = night (s); SWD = shift work disorder.

Table 2. Summary of longitudinal studies

Authors/ date	Study method	Sample	Research topic	Measures	Main results
Saksvik *et al*. (2011)[38]	Daily sleep diary completion and actigraphy recordings for one week before work, during a two week work period and one week following work for three different work schedules (14D, 14N, 7N/7D) 12 h shifts.	19 oil installation workers in the North Sea, 6 females, 13 males. Mean age 44.4 yr. Response rate 87.5%. Sample as for Harris *et al*. (2010) and Waage *et al*. (2012) (Norway).	Adaptation to shift work, sleep during two weeks of work and re-adaptation after the work period.	Subjective and objective (actigraphy) sleep measures.	Sleep efficiency was higher during day work than night work and swing shift. Sleep quality was better during swing shift than during day work and night work the first week of work. Sleep duration was shorter during swing shift than regular day work and night work. In terms of sleep, adaptation to swing shift seemed more difficult than adaptation to day work and night work. Small differences in re-adaptation between different shifts.
Waage *et al*. (2012)[39]	Participants were monitored for four weeks; one before, two during and one after the shift work. Assessment was repeated for three different shift schedules lasting for two weeks (14D, 14N, or 7N/7D).	19 North Sea oil rig workers (6 females, 13 males), mean age 44.4 yr. Response rate 87.5%. Sample as for Harris *et al*. (2010) and Saksvik *et al*. (2011) (Norway).	Sleepiness during offshore work. Adaptation to night work and re-adaptation to daytime schedule.	Sleep and wake diary completed daily, reaction time tests performed six times during each work period.	Sleepiness was highest during the first days of swing and night shift, during night shift it decreased. When swinging to day shift a new peak in sleepiness was found during daytime. Reaction time tests during the work period showed no significant differences between the shift schedules. There was a significantly shorter reaction time the last day compared to the beginning or middle of the work period. At home, sleepiness was higher following night shift compared to following swing shift. Adaptation to night work happened within a few days according to subjective measures.
Waage *et al*. (2012)[40]	Questionnaire administered twice during a two week work period with 12 h shifts; during the first and last workday.	Oil rig workers in the North Sea working two weeks of day shift (n=90) or two weeks of a swing shift schedule (7N/7D) (n=93). 176 males and 5 females. Mean age 42.9 yr. Response rate 72.6% (Norway).	Subjective sleep and subjective health complaints.	Sleep and insomnia symptoms, subjective health complaints.	Workers reported significantly poorer sleep quality and more complaints of insomnia at the end of the work period than at the start. No significant difference in subjective health complaints between the groups. No clear differences in changes in sleep quality, insomnia or subjective health complaints during the work period between day and swing shift workers. Higher proportion of insomniacs among swing shift workers than day workers at the end of the work period.
Barnes *et al*. (1998)[41]	Urine samples collected several times a day during two weeks of day shifts and two weeks of night shifts. 12 h shifts were worked.	11 male subjects studied in winter; six maintenance workers (mean age 36.7 yr) and five drill crew members (mean age 45.0 yr). 23 male engineers studied in summer, mean age 37.5 yr. North Sea (UK).	Adaptation to night work.	Changes in 6-sulphatoxymelatonin (aMT6s) acrophase.	The subjects showed adaptation to night shift by delay of the aMT6s rhythm within the first week. No seasonal differences in adaptation rates were found.
Gibbs *et al*. (2002)[42]	Urine samples collected several times a day during two weeks of swing shift (7N/7D), 12 h shift duration.	11 male swing shift workers from two oil installations in the North Sea, mean age 44.7 yr (UK).	Adaptation to night work and re-adaptation back to day work.	Adaptation of circadian phase, assessed by aMT6s acrophase.	8 of 11 subjects adapted to night shifts indicated by a delay of the aMT6s rhythm, two subjects did not adapt to nights, while one subject appeared to be adapted to night shift before the study started. Large individual variations in the subsequent adaptation to day work; two subjects continued to phase delay, one subject showed phase advance, and five subjects did not change their phase position.
Gibbs *et al*. (2007)[43]	Collection of urine samples several times a day for two weeks of swing shift (7N/7D). Actigraph worn continuously. Shift duration was 12 h.	23 male offshore swing shift workers in the North Sea, mean age 40.2 yr (UK).	Adaptation to night work and back to day work.	Changes in aMT6s acrophase. Actigraph measuring activity.	19 of 23 subjects adapted their aMT6s rhythm to night shift by delay. Of the 19 night adaptors 7 showed little phase change, 6 continued to phase delay and 6 phase advanced when swinging back to day shift. Only the latter group achieved full re-adaptation within a week.

Table 2. continued

Authors/ date	Study method	Sample	Research topic	Measures	Main results
Thorne *et al*. (2008)[24]	Urine samples collected every four hours during the last three days of 14 or 21 days of fixed night shifts. Sleep diary completed daily. Actigraphy recordings. Comparison between two night shift schedules (1800–0600 and 1900–0700). Shift duration as 12 h.	Two groups of male night shift offshore personnel, N=10, mean age 46 yr, and N=7, mean age 41 yr (UK).	Adaptation to night work.	Changes in aMT6s acrophase. Subjective and objective sleep. Actigraphy to assess activity.	14 of 16 night workers showed circadian adaptation to night shift. Adapted workers (1900–0700 hours) had significantly later acrophase assessed by actigraph compared to adapted subjects working 1800–0600 hours.
Barnes *et al*. (1998)[44]	Urine samples collected several times a day during two weeks of swing shift (7D/7N). Sleep reports completed daily and wrist activity monitor worn continuously for two weeks, 12 h shifts.	Two male drill crews in the North Sea, 11 studied in November, mean age 34.6 yr and 7 studied in March, mean age 32.6 yr (UK).	Adaptation to night work.	Changes in aMT63- acrophase. Sleep during work period.	The crew studied in November showed no change in aMT6s rhythm during night shift, while the crew studied in March showed a significant phase advance of the rhythm during night shift. Sleep duration was significantly shorter on night shift in November. Season may affect adaptation.
Harris *et al*. (2010)[29]	Offshore workers followed during three two-week work periods (14D, 14N, 7N/7D) They were monitored for four weeks; one before, two during and one after the shift work. Shift duration was 12 h.	19 oil rig workers in the North Sea. 6 females, 13 males. Mean age 44.4 yr. Response rate 87.5%. Sample as for Waage *et al*. (2012) and Saksvik *et al*. (2011) (Norway).	Effects of changing from fixed day/night shifts to 7N/7D swing shifts in terms of cortisol rhythm, reaction time and health. Adaptation and re-adaptation.	Cortisol assessed via saliva 5 times each test day (3 or 4 days during 2 weeks at work). Reaction time assessed at start and at end of each shift. Health complaints and perception of work assessed at baseline (fixed shift) and when working swing shift (7N/7D).	Swing shift gave no negative health effects or negative changes in reaction time during the day they shifted from night work to day work. Adaptation to night shift was complete within a week regardless of schedule, while recovery from night shift took a longer time. Following swing shift, the cortisol rhythms were readapted one week after the work period. The rhythms were not readapted after one week at home following fixed night shift.
Bjorvatn *et al*. (1998)[45]	Sleep diary completed daily during two weeks of night work and during the first week after returning home. Questionnaire completed after the night work period and after the re-adaptation period at home. Shift duration was 12 h.	7 male oil platform workers in the North Sea, mean age 38.9 yr. Sample as for Bjorvatn *et al*. (1999) (Norway).	Adaptation to night work and daytime schedule at home.	Subjective sleep and sleepiness.	Adaptation to night work was complete within a few days, indicated by rapid reduction in sleepiness. Re-adaptation to daytime schedule at home was slower and more difficult. Subjective sleepiness was higher during the week at home, compared to the two weeks working nights.
Bjorvatn *et al*. (2006)[46]	Placebo group in an RCT. Serial reaction time tests at 3 time points during 3 nights/day of each week of a two week swing shift period (7N/7D), daily sleep diary, actigraphy monitoring, and questionnaire administered after the work period. Shift duration was 12 h.	17 offshore drilling rig personnel in the North Sea with self-reported shift work adjustment problems. Mean age 42 yr. One female, 16 males. Sample as for Bjorvatn *et al*. (2007) (Norway).	Adaptation to night work and re-adaptation to day work.	Sleep and sleepiness. Perceived adaptation and re-adaptation.	Subjective and objective measures of sleep and sleepiness gradually improved during night work. The return to day work after 1 week of night shift caused an increase in subjective sleepiness and worsening of sleep parameters. Sleep and sleepiness gradually improved during the week of day work.
Bjorvatn *et al*. (1999)[47]	Baseline (control), thereafter one condition with bright light treatment administered the first four nights of 14 night shift and the first 4 days at home, scheduled individually to phase delay the circadian rhythm. Daily data collection during two weeks of night work offshore and one week at home, using sleep diary. Questionnaires were answered following shift work and following re-adaptation period at home. Shift duration was 12 h.	7 male night shift workers in the North Sea, mean age 38.9 yr. Sample as for Bjorvatn *et al*. (1998) (Norway).	Adaptation to night work and daytime schedule at home.	Self-reported sleep and sleepiness. Subjective adaptation and re-adaptation.	No significant effect of light treatment was found during night shifts. Bright light treatment at home led to significantly better self-reported sleep and reduced sleepiness compared to the control condition, and improved also daytime functioning.

Table 2. continued

Authors/ date	Study method	Sample	Research topic	Measures	Main results
Bjorvatn *et al*. (2007)[48]	Randomized placebo-controlled, crossover study. Participants received placebo, melatonin or bright light treatment during the first four days of night shift or day shift. The workers worked swing shift during all conditions (7N/7D), 12 h shifts.	17 offshore drilling rig personnel in the North Sea with self-reported shift work adjustment problems. Mean age 42 yr. One female, 16 males. Sample as for Bjorvatn *et al*. (2006) (Norway).	Effects of melatonin and bright light treatment on adaptation to night work.	Daily sleep diary completion, actigraphy monitoring, serial reaction time tests and questionnaires.	Sleep diary and questionnaire showed that melatonin reduced sleepiness, increased sleep duration, improved sleep efficiency and improved the "quality of the day" during day shift. Bright light treatment gave a modest reduction in sleep onset latency during night shift, compared to placebo and melatonin. Melatonin reduced the number of days needed for re-adaptation compared to bright light, while the placebo condition reached an intermediate level. Actigraph showed that melatonin increased sleep onset latency compared to bright light and placebo during day work.
Thorne *et al*. (2010)[49]	Randomized crossover design, subjects assessed for 21 days; the last week of two or three weeks of night shift work and the following two weeks at home. In one condition the subjects wore sunglasses from wake-up until they received light treatment beginning at 1300 h the first day, on subsequent days beginning earlier. In the other condition no intervention was given. Shift duration was 12 h.	Male offshore night shift workers in the North Sea, N= 10, 9 or 8 (for different measures), mean age 46 yr and 49 yr (UK).	Effects of light treatment on sleep and adaptation from night work to daytime schedule at home.	Questionnaires, daily sleep diary completion, actigraphy recordings, urine samples collected several times a day for three weeks.	As measured by actigraph, sleep efficiency was improved during light treatment work period. After the light treatment, sleep onset was significantly earlier and sleep duration was significantly longer. Subjective data showed a decrease in sleep quality in the light treatment condition. aMT6s measures showed no effect of light on circadian adaptation.
Lauridsen & Tønnesen (1990)[54]	Analysis of drilling injuries in Norwegian offshore oil production.	Information regarding 3,200 injuries in the period 1980–1987, retrieved from the Rogaland Research Institute's data base "Injuries in Offshore Drilling" (Norway).	Injuries.	Injury rates.	There was no difference between day and night shifts in terms of injury rate among active drilling crews. The was a significant increase in number of injuries between 0000 and 0600 hours, as compared to between 1800 and 2400 hours.

D = day (s); N = night (s); aMT6s = 6-sulphatoxymelatonin; RCT = randomized controlled trial

aMT6s acrophase showed no evidence of faster adaptation in the treatment condition. One of the abovementioned intervention studies also assessed the effect of melatonin administration on adaptation, which was found to be marginally more effective than the light treatment[48].

Overall, the three intervention studies indicated that bright light treatment and melatonin administration aiming to improve adaptation to shift work offshore may give significant, albeit small, positive effects[47–49]. The interventions seemed to be more effective in improving re-adaptation following night work.

Shift work and health

Six cross-sectional studies examined the relationship between shift work and health.

One study demonstrated that the offshore workers had significantly higher anxiety scores than onshore workers across day work, night work and the off work period[32]. In two separate studies, day/night workers reported higher scores of psychological distress than day workers[33, 50]. However, the effect of shift work in predicting higher mental distress disappeared in both studies when controlling for individual factors or job type[33, 50].

Two studies regarding body mass index (BMI) have compared offshore day workers with offshore day/night workers. In one of these, continued exposure to day/night shift work was associated with increased BMI[51], while in the other study day/night shift workers had significantly lower BMI scores than day workers[33]. The latter study also demonstrated that shift work predicted gastric problems[33]. A separate study found no differences between offshore shift workers and onshore workers in somatic symptoms such as tiredness and headaches, or in social dysfunction[32]. Two studies compared offshore workers across different shift schedules; one found no association between shift type or shift work exposure and subjective health complaints[34], while in the other, no differences were found regarding subjective health complaints between shift workers without SWD and day workers[6]. In the latter study, subjects with SWD reported more subjective health complaints than individuals without SWD[6].

One longitudinal study assessing subjective health complaints found no differences between fixed shifts and swing shifts[29)], similar to another study that found no differences in subjective health complaints between day workers and swing shift workers[40)].

Overall, few studies have investigated the relationship between shift work and health offshore, and their findings are inconclusive[32, 33, 50)]. The findings regarding BMI are also inconsistent[33, 51)]. Further, it appears that shift work is a predictor for gastric problems[33)]. There is no evidence for more subjective health complaints among offshore shift workers compared to offshore day workers, except in the group of shift workers fulfilling the criteria for SWD[6)].

Shift work and family/social life

Two cross-sectional studies examined the impact of shift work on social and family life. A qualitative study with no contrast group found that shift workers offshore had difficulties in reconciling work with family life[35)]. In the other study, the majority of shift workers across all shift schedules reported few problems with social and family life caused by shift work, and in this regard offshore workers were better off than their onshore counterparts[52)]. In sum, the results from these two studies are inconsistent regarding whether offshore shift work is related to problems with family and social life.

Shift work and accidents/safety

One study demonstrated that with no control for job type, shift work predicted work-related injuries[33)]. In another study, the accident registry for an offshore unit was examined, finding that 17 accidents were recorded during the past year[35)]. Nine accidents took place between 0600 and 1800 hours, while eight happened between 1801 and 0559 hours. Taking into account the uneven distribution of workers at night /daytime, they calculated that the relative risk of accidents was 51% higher during the dark period between 1801 and 0559 hours[35)]. Further, one study analyzed information regarding 3200 drilling injuries in the Norwegian offshore oil production between 1980 and 1987, and found that there was no difference between day and night shifts in the injury rate among active drilling crews[53)].

Four studies have used serial reaction time tests in order to obtain objective measures of sleepiness and performance. Reaction time measures may be relevant for accidents and safety. Findings from three longitudinal studies demonstrated that, with one exception, there were no significant differences in reaction time across different shift schedules[29, 39, 46)]. Further, two of the studies found a reduction in reaction time across days for the night shift[39, 46)]. Also, a small, but significantly higher mean score in reaction time the first night offshore, when on night shift compared to day shift, was found[29)]. In an intervention study, no significant differences across night shift and day shift in terms of reaction time were found[48)]. During day shift however, this study demonstrated an increased reaction time after intake of melatonin and exposure to bright light during the first day after swinging from night to day work[48)].

In total, two studies regarding accidents and safety have demonstrated that shift work increased the risk of work-related accidents, and that the relative risk of accidents was higher during the night than day[33, 35)]. One study reported no differences in injury rates between day and nighttime in active drilling crews[53)]. The findings from reaction time tests gave no indication that reaction time is longer during night shift work[29, 39, 46)].

Shift work, work perceptions and perceived mastery of work

One study comparing the work perceptions (referring to perceived work environment measures, including physical stressors, job demand, job control, skill discretion, supervisor support, and safety perceptions) among day and shift workers across onshore and offshore settings showed that differences between day and shift workers were less marked in the offshore setting; the only significant difference offshore was that shift workers reported significantly greater exposure to physical environmental stressors than day workers[30)].

Another study investigated factors related to perceived mastery of work (referring to an individual's perception of the desirability of his/her effort at work), and found that night work was unrelated to perceived mastery of work in a multivariate analysis[54)]. In the same study it was shown that offshore workers reported higher levels of perceived mastery of work than a control group.

Overall, offshore shift workers reported greater exposure to physical environmental stressors than offshore day workers[30)]. Night work seems to be unrelated to perceived mastery of work among offshore workers[54)].

Discussion

In the present review we have explored studies concerning effects of shift and night work on employees in the offshore petroleum industry. Twenty-nine studies with outcome measures in terms of sleep, adaptation, health, family- and social life, safety, and work perceptions were included.

The findings concerning sleep parameters such as quality and duration of sleep are somewhat inconsistent regarding whether day or night workers are better off[28, 31, 34, 36, 37]. However, the majority of studies found that offshore day shift workers reported better sleep quality, longer sleep duration and fewer sleep problems such as difficulty falling and staying asleep, and fragmented sleep, than offshore night shift workers[28, 31, 33, 37]. These findings are in line with research conducted on shift workers onshore, where shift work has been found to be associated with difficulties falling asleep, shortened sleep duration, and increased fatigue[4]. The SWD prevalence of 23.3% obtained in the offshore study is midway between the prevalence in studies from onshore settings[6–8]. Inconsistent findings may be related to methodological differences between the conducted studies. Some studies have employed sleep and sleepiness measures exclusively based on self-reports, such as questionnaires, sleep diaries and interviews, while others have used objective measures of sleep such as actigraphy. These methodological differences may yield differing results, as research suggests that responses to sleep questionnaires only are moderately correlated with actigraph-measured sleep[55].

The main findings regarding adaptation of circadian rhythms were that the most workers were fully adapted to night work within one[29, 39, 41–43, 45, 46] to two or three weeks[24]. It appears that full adaptation to night work offshore may be more common and easier to achieve than adaptation to night work onshore, as only a small minority of onshore night workers evidenced complete adaptation[9]. This may be related to the fact that the offshore environment is better adapted to 24 hour operations with similar routines for day and night shift workers, making it easier to entrain the circadian rhythm to the working environment. Morning exposure to light may prevent a phase delay[56]. Little exposure to morning light in night workers in the offshore petroleum industry has been suggested as a major reason for faster adaptation offshore[45]. Complete adaptation to night work is beneficial when working nights. However, there is also a disadvantage with the complete adaptation, in that re-adaptation back to a daytime schedule may become more difficult. Several studies in this review showed that re-adaptation from night work back to a daytime schedule offshore or at home was slower than adaptation to night work[29, 42, 45]. Given that adaptation to night work is easier offshore, one might predict that re-adaptation back to a daytime schedule is more difficult offshore than onshore, which is in fact what most studies in the present review indicated. Several different methods have been used to measure adaptation to and re-adaptation from night work (e.g., hormones such as aMT6s and cortisol, actigraphy and sleep/sleepiness questionnaires and diaries, as well as reaction time tests). Yet, the findings from studies in this review indicate that the results are largely consistent across measurement methods.

The three intervention studies indicated that specific interventions aiming to improve adaptation offshore may give small albeit significant, positive effects, whereas interventions seemed to be more effective in improving re-adaptation following night work[47–49]. This is in line with previous findings from both simulated night work studies and field studies, suggesting that bright light interventions and melatonin administration may improve adaptation to night work - for a review, see Pallesen *et al.*[57].

Few studies have investigated the relationship between shift work and health offshore. Findings from studies conducted onshore indicate that shift work is a risk factor for poor mental health[18, 19], however, findings from the offshore petroleum industry are somewhat more inconclusive[32, 33, 50]. The findings from offshore studies regarding BMI are inconsistent[33, 51], and do not exclusively support the findings from onshore studies with shift work being a risk factor for increased BMI. Further, it appears that shift work is a predictor for gastric problems[33], an association that has also been found in studies onshore[12]. There is no evidence for more subjective health complaints among offshore shift workers compared to day workers, except in the group of offshore shift workers fulfilling the criteria for SWD[6]. Overall, these studies are too few in number to justify general conclusions about health-related effects of shift work. In onshore studies, night work seems to be a risk factor for breast cancer among women, however, none of the studies included in this review concern risk for cancer. Neither has any studies regarding reproductive health been conducted. More research regarding health effects of offshore shift work is therefore warranted. Also, it should be noted that the studies in this review mainly or exclusively include male subjects.

Only two studies concerning family and social life have been conducted[35, 52], finding inconsistencies in whether shift work is associated with problems with family and social life. One of these studies[35] supports the finding from onshore research that working shift may be associated with conflict between work and family/social life[22].

Regarding accidents and safety, two studies have demonstrated that shift work increased the risk of work-related accidents, and that the relative risk of accidents is higher during the night[33, 35]. This is in line with research conducted onshore, where shift and night work have been shown to increase the risk for work-related accidents[10]. However, one study reported no differences in injury rates between day and nighttime in active drilling crews[53]. The findings from reaction time tests gave no indication that reaction time is longer during night shift.

Overall, it appears that shift work and night work offshore are more problematic than day work offshore. This is largely consistent with findings from onshore settings[58]. Further, compared to onshore shift workers, offshore shift workers do not seem to be much worse off. This may be somewhat surprising, as the working conditions for offshore workers are assumed to be harsher than those of the onshore workers. However, the findings may be related to the fact that offshore workers constitute a highly selected and healthy population as the oil industry has strict regulations in terms of health and medication use, and all personnel have regularly health checks. Thus, the offshore workers may be better able to handle the different and perhaps worse working conditions, and it may therefore appear as if the effects of shift work offshore are not particularly worse than shift work onshore. It should also be noted that the offshore work environment (e.g., no commuting time, working mainly indoors and no domestic obligations) may facilitate adaptation to night work to a larger extent than onshore work environment[38].

Limitations

Some limitations of the present review should be noted. Firstly, the results might be affected by publication bias, as only published research was included. Research reports were also excluded due to the uncertainty of their scientific quality, as they have not been peer-reviewed; hence relevant findings may have been lost. Second, only studies written in English were included. It should be noted that some of the articles based on longitudinal data are not independent from each other, as some of them are derived from the same studies (e.g.[45, 47]).

There are currently several limitations in the research field that should be taken into consideration when interpreting the results. In general, among studies investigating effects of shift and night work in the offshore petroleum industry, relatively few have been published in peer-reviewed journals. Few longitudinal studies on other outcome measures than adaptation and sleep exist. Evidence from the onshore petroleum industry demonstrates that shift work is related to a wide range of negative health consequences, however, few cross-sectional and no longitudinal studies on this relation have been conducted offshore, e.g. only two studies examine BMI changes and none have assessed cancer, cardiovascular health or reproductive health. Further, research on accidents related to shift work offshore is scarce, as is that on its relation to family and social life. Also, the studies concerning health, accidents, family and social life, work perceptions, and some studies concerning sleep, have been cross-sectional in nature; and one can therefore not draw any conclusions about cause and effect from these studies. The methodological design varies greatly across studies, making direct comparison of findings difficult. The category of shift workers includes both those working fixed night shifts and those working swing shift. Additionally, the comparison groups across the different studies vary. In general, it is difficult to find adequate reference groups for these studies. In six of the 29 studies included in this review, offshore shift workers are compared to onshore workers[30, 32, 36, 37, 52, 54]. In eight studies, offshore shift workers are compared to offshore day workers[6, 28, 31, 33, 34, 40, 50, 51], one study compared two different groups of night shift workers[24] while in 12 studies, the same offshore workers are compared across different shifts[29, 38, 39, 41–49]. Two of the studies have no comparison group at all, i.e. the study based on qualitative interviews[35] and the study of analysis of drilling injuries[53]. An additional issue is the various definitions of shift work used across studies[59]. These methodological issues support the notion that one should be cautious when trying to draw general conclusions from these studies.

As previously mentioned, offshore employees constitute a selected and healthy population. Thus they probably differ from shift workers onshore, and this complicates comparison of results between offshore and onshore settings. The latter may also make these kinds of comparisons less informative, and may suggest that comparisons across groups of offshore workers (e.g., day vs. night workers) are more informative.

The number of participants across the offshore studies varies greatly from 7[45, 47] to 9,601[31]. Non-significant findings may in some of the smallest studies reflect lack of statistical power, rather than absence of relationships[60].

The vast majority of studies derive from Europe; more specifically, 27 of the studies stem from the Norwegian and the UK offshore sector. Only two of the studies have been conducted outside Europe (Brazil). A large proportion of the worldwide offshore oil and gas industry is situated in the North Sea, and it is therefore rather natural that most studies derive from this area. More research conducted outside of Europe and the North Sea is still warranted in the future.

Implications for future research

Generally, the relatively few studies conducted and the inconsistent findings in the field give rise to a need for more research about the effects of shift work in the offshore petroleum industry. More longitudinal research would be beneficial in order to investigate long-term effects of working offshore in the petroleum industry, but also to investigate day-to-day variations on outcome variables over different shifts to establish short-term changes in e.g. health, sleep and well-being. This need is especially pronounced concerning health effects, as there is a lack of longitudinal studies concerning health in offshore shift workers. Future offshore shift work studies should aim at including objectively measured metabolic and cardiovascular parameters. Studies concerning the risk of cancer and gastrointestinal disorders/symptoms as a consequence of shift work, preferably assessed by objective measures, should also be prioritized in future offshore studies. Further, as the geographical areas covered by the present studies are rather restricted, research from other parts of the world is warranted. Another gap in current knowledge regards individual factors that may influence adaptation to and also effects of shift work offshore. As research from work settings onshore indicates that personality variables such as neuroticism, extraversion, morningness, hardiness, flexibility and languidity influence the tolerance to shift work[61], future studies should focus upon this issue.

Conclusion

The longitudinal studies were generally consistent in showing that adaptation to night work was complete within one to two weeks of work, while re-adaptation to a daytime schedule was slower. Shift workers reported more sleep problems than day workers. The data regarding mental and physical health, family and social life, and accidents yielded inconsistent results, and were insufficient as a base for drawing general conclusions. More research in the field is warranted.

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