Working hours in the offshore petroleum industry

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The remote location of North Sea oil and gas installations necessitates an extended work pattern; typically, offshore workers spend two weeks offshore followed by a period of shore leave. On Norwegian installations, offshore tours are normally limited to a maximum of two weeks; currently, the pattern most frequently worked is two weeks offshore, alternating with 4 weeks shore leave (2-4 pattern)[a], although prior to 2002 an asymmetric 2-3-2-4 pattern was in operation[1]. On installations in the UK North Sea sector, the most common work pattern is two weeks offshore alternating with two weeks shore leave (2-2 pattern). Less frequently, 3-3 or 2-3 patterns (or combinations of 2-2 and 3-3 schedules) are worked. Specialist personnel, who frequently move between different installations, often have irregular and/or unpredictable work patterns in both the Norwegian and UK sectors.

At any one time, only two crews can be accommodated on board; thus, the standard shift duration is 12 hrs for day/night shift workers operating continuous processes such as drilling and production. Shift duration for day workers offshore is also 12 hrs; a two-week tour therefore involves a minimum of 168 hrs work, although some personnel (especially managers and supervisors) may work much longer hours. Working hours on installations in the UK sector of the North Sea are now subject to the provisions of the European Working Time directive, as amended in 2003 to apply to ‘other work at sea’, although there is currently some uncertainty as to exactly how the directive should be interpreted. The Norwegian North Sea sector has adopted similar working time arrangements.

Research into long work hours

The effects of extended work hours and shift patterns, on performance, illness, and accidents, have been widely studied in onshore work settings, and several review articles have been published[2-4]. Theoretical models have also been developed to represent the effects of extended work hours on fatigue, human error, and health[5-7], and to predict risks associated with particular shift patterns[8,9]. However, research in onshore settings does not fully address the issues raised by work patterns covering round-the-clock operations in remote offshore locations. The present review therefore focuses primarily on research findings derived directly from offshore environments, although also drawing on some relevant onshore studies. Moreover, the material presented relates only to offshore oil and gas installations (i.e. production platforms, drilling rigs, and

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[a] In this document, work patterns show the leave weeks in bold type

FPSO vessels); it does not include research into shipping operations.

Overview of risks associated with offshore work patterns

Work on offshore installations involves potentially hazardous production and/or drilling operations. The concentrated work patterns, the nature of the tasks involved, and the effects of fatigue, are potential sources of risk to the safety and well-being of personnel. Two types of risks can be distinguished, operational risk (e.g. risk of explosion, fire, structural failure, shut-down, reduced productivity) resulting from human error, and risk to the physical and psychological well-being of individuals (e.g. injury, illness, sleep disturbance, anxiety).

The adverse effects of long work hours and fatigue are common to both types of risk. Moreover, offshore personnel have to remain on the installation during off-shift hours; leisure activities are restricted to the facilities available on board, and sleep periods to the cabin accommodation provided. On Norwegian installations, most personnel have sole occupancy of a cabin for sleeping (either a single cabin, or a two-man cabin shared by one crew member from the night shift and one from the day shift). However, on UK installations, normal accommodation is a shared two-man cabin. Thus, the quality of short-term rest and recovery from work-related fatigue may be impaired, even though extended periods of leave, alternating with offshore work periods, may allow longer-term recovery.

Over and above the demands of long work hours per se, several aspects of offshore work schedules may accentuate operational and individual risks. The most significant of these is day/night shift rotation, particularly the effects of circadian disruption and sleep disturbance associated with night work. A substantial proportion of offshore personnel are employed in jobs (such as drilling and production) which require day/night shift work. Thus, in a recent large-scale survey of personnel (N=9945) on Norwegian installations, 33% of respondents were day/night shift-workers, 43% were day-workers, and the remainder worked nights only (<3%) or varying schedules (22%)[10]. In a survey of UK sector offshore workers (N=1462), 45% reported working day/night rotating shifts[11].

Several different patterns of day/night shift rotation are in use on North Sea installations. ‘Fixed-shift’ patterns are those in which either 14 day shifts or 14 night shifts are worked over a two-week tour, and the alternate shift is worked on the next tour. ‘Rollover’ patterns involve a shift change at the end of the first week, either ‘days-to-nights’ or ‘nights-to-days’. Both fixed-shift and rollover patterns are operated in the Norwegian and UK sectors. On Norwegian installations, 47% of day/night shift workers reported working fixed-shift patterns[10], whereas on UK installations, rollover patterns were reported by the majority (64%) of day/night shift workers[12].

Although shift work is a major concern in relation to operational and individual risks, other aspects of working time offshore are also relevant. For instance, some personnel regularly work overtime hours (i.e. longer than 168 hrs in the two-week period), and/or tour durations of longer than two weeks. The extent to which these extended hours give rise to decrements in performance, and hence increased risk of errors, merits attention. Indeed, 'fatigue from shift work and overtime' is high on the list of human factors 'Top Ten Issues' identified by the UK Energy Institute[13]. It is also necessary to consider ways in which individual (e.g. age) and environmental (e.g. physical and psychosocial stressors) factors may act to accentuate or mitigate the effects of long work hours offshore.

Operational risks associated with offshore work hours

Long work hours are an integral feature of offshore employment. Thus, fatigue is a potentially serious problem for all offshore workers, particularly those exposed to the additional demands of circadian adaptation necessitated by night work. From the point of view of operational risks, the extent of performance impairment and reduced alertness over the course of individual 12-hr shifts, and over the course of a 14-day offshore tour, are the main concerns. Information about sleep patterns is also important in considering human error and operational risks, as inadequate recovery from work at the end of a shift may lead to an accumulation of fatigue during the later days of the tour.

The effects of extended overtime hours, and of working 12 hr shifts for seven consecutive days, have been studied in onshore occupational groups[14,15], but schedules of consecutive 12-hr shifts extending more than a week are rare in onshore industry. However, in the offshore environment, the effects of working 12-hr shifts over two-week tours have been examined[12,16,17]. These studies used electronic diary methods to make repeated assessments of cognitive performance (as assessed by standard laboratory tasks), subjective alertness, and/or sleep. Parkes et al.[12] compared fixed-shift patterns with 'rollover' patterns using cognitive tasks and subjective rating scales. Smith[16] followed a similar approach, while Bjorvatn et al.[17] focused on the nights-to-days 'rollover' pattern, combining objective and subjective assessment methods.

In addition, a series of studies has been carried out into circadian adaptation and sleep among offshore workers[18-20]. These studies used the circadian rhythm marker 6-sulphatoxymelatonin to assess adaptation to 'fixed-shift' and 'rollover' rotation patterns; the data collected by Gibbs et al.[18] also included objective measures of sleep (using actimetric recording), assessment of exposure to light, and several physiological measures.

In the following sections, the main findings relating to 'fixed-shift' sequences of 14 days/14 nights, and two 'rollover' patterns (7 days/7 nights, and 7 nights/7 days) are outlined.

14 day shifts (07.00-19.00 hrs)

Patterns of subjective alertness, performance, and sleep over the sequence of 14 day shifts (14D) are generally found to be relatively stable, and in line with onshore data. For instance, Parkes et al.[12] reported mean reaction times (RT) consistent with published values, mean sleep hours of 6-7 hrs each night, and alertness ratings generally in the positive range. Alertness decreased significantly from mid-shift to end-of-shift, but these decrements did not increase over the 14-day tour. Mean RT speed did not change (although RT variability tended to increase) over successive days-into-tour. Sleep quality was markedly low on the first night offshore relative to subsequent nights.

In a separate study, subjective alertness and performance were assessed before and after each shift during a 14-day tour[16]. As large amounts of data were missing, the analyses were restricted to Days 2, 7, and 13. Slower RT responses were found for Day 13 (due to an abnormally high value for the before-shift measure on that particular day) as compared with Days 2 and 7, but there was no corresponding increase in errors or in lapses of attention, and no similar pattern for subjective alertness measures.

The relative stability of measures across 14D shift pattern reflects the fact that this shift sequence involves only day work and does not disrupt the normal circadian rhythm[18]; in this study, mean sleep duration (derived from actimetric recordings) was found to be 6.27±1.17 hrs per night across the two-week tour.

14 nights (19.00-07.00 hrs)

Studies of adjustment to sequences of 14 night-shifts (14N) are consistent in indicating that adaptation to night work usually takes place in the first 5-6 days offshore[12,16,18,19,21]. Thus, full physiological circadian adaptation to night-shift work was found to occur within the first week of the 14N schedule[18], confirming earlier findings[19]. Similarly, Parkes et al[12] reported that mean subjective alertness increased across the first week of the 14N shift pattern, sleep quality also improved, and end-of-shift RT decreased, as adaptation progressed across the 14 night shifts.

In a longer study[21], data collection was continued beyond the sequence of 14 night shifts to evaluate re-adaptation back to a normal circadian cycle. Sleep ratings were assessed daily over the 14N sequence offshore, and over the first week of shore leave; the results suggested that adaptation to night work offshore was less problematic than re-adaptation to a normal diurnal cycle on returning home.

7 days / 7 nights, production personnel: (07.00-19.00 hrs / 19.00-07.00 hrs)

The 7D/7N rollover schedule imposes no demand for circadian adaptation during the first day-shift week but sleep, performance and alertness are disrupted during the initial part of the second week by the change to night shifts, although the extent and duration of impairment differs for different outcomes. Thus, sleep duration and quality showed significant impairment immediately after the shift change, but only sleep quality continued to be impaired throughout the second week[12]. Subjective alertness also showed a sharp decrease during the first two night shifts; although start-of-shift alertness recovered in subsequent shifts, end-of-shift alertness levels remained markedly low.

Consistent with the findings for subjective alertness, RT responses were found to be approximately 11% slower (as compared with the 14D group) during the three shifts following the change to night work, and gaps in RT responses (i.e. trials in which no response was made in 1 second) increased significantly over these days. In a separate survey study, the 7D/7N schedule received the least favorable ratings on a measure of ‘satisfaction with shift rotation’[12].

7 days / 7 nights, drill crew (00.00 - 12.00 hrs / 12.00 - 24.00 hr)

Unlike production personnel, drill crews traditionally change shifts at midnight and midday. Two studies of the 7D/7N pattern worked by offshore drill crew have been reported. In a study of circadian adaptation, sleep duration and sleep quality were impaired for several days following the shift change; reduced sleep duration continued throughout the remainder of the tour[18]. A further study of this schedule found few significant effects, possibly due to the small sample size[16].

7 Nights / 7 Days ‘rollover’ shift pattern (19.00-07.00 hrs / 07.00-19.00 hrs)

The ‘rollover’ shift pattern of 7 night shifts followed by 7 day shifts (7N/7D) is more commonly used than the 7D/7N pattern on UK and Norwegian production installations. It is strongly preferred by many offshore workers as it allows them to leave the installation adjusted to a normal daytime circadian cycle at

the end of each tour[12]. This issue is of particular importance to UK offshore personnel, who normally have only two weeks shore break between tours; thus, circadian re-adjustment after night shifts offshore may take up almost half the shore break. However, in terms of sleep, performance and alertness, the 7N/7D pattern is the least favorable of the rotation patterns in use in the North Sea environment. The main problem of this schedule is that it imposes two 12-hr circadian changes during the two-week tour (to night shifts on arrival offshore, reverting to day shifts at the end of the first week).
Research highlights the adverse effects of the 7N/7D schedule; in particular, studies of circadian adjustment and sleep patterns[18,20] indicate that, although adaptation to night work occurs by the end of the first week offshore, full re-adaptation back to daytime schedules does not occur during the day-shift week for the majority of personnel. Thus, optimal performance may only be achieved for a total of 4-6 days during a 14-day tour; for the other 8-10 days, there is an increased risk of human error.

Consistent with these findings, impairment in measures of alertness and sleep was observed throughout the second week of the 7N/7D schedule, with little evidence of re-adaptation to day work[12]. A more detailed study of this schedule used subjective rating scales and objective measures (reaction time task, and actimetric assessment of sleep) to assess circadian adaptation in a group of offshore workers who reported difficulty adjusting to shift work[17]. Sleep and performance showed progressive improvement over the week of night work, but sleep was significantly impaired at the start of the day-shift week. In general, the findings were more marked for subjective measures than for the objective measures.

Comparison of shift rotation patterns in terms of adaptational load

'Desynchrony load' provides an overall indicator of the disruption that a particular rotation schedule causes to the circadian system over the tour duration. It thus allows direct comparison of the circadian adjustment demands imposed by different rotation patterns. Desynchrony load values were found to be 13.95 hrs (14D fixed shift), 27.98 (14N fixed shift), 26.23 hrs (7D/7N rollover schedule), and 61.7 hrs (7N/7D rollover schedule), although the authors noted that the 7D/7N value might be an under-estimate.[18]

The relative magnitudes of the load values for the different shift rotations accords closely with those of the 'sleep deficit' values reported by Parkes et al[12]. These sleep deficits (derived from a combination of diary and survey assessments) estimate the sleep hours lost for different shift patterns during a two-week offshore tour, relative to sleep during shore leave periods. The values were 12.6 hrs (14D), 16.4 hrs (14N), 17.7 hrs (7D/7N) and 20.3 hrs

(7N/7D).

Both ‘desynchrony load’ and estimated ‘sleep deficits’ highlight the severe adaptational demands imposed by the 7N/7D schedule, and hence the potentially greater operational risk associated with this schedule. This finding contrasts notably with the strong preference of the majority of offshore shift workers for the 7N/7D schedule.

Relative advantages and disadvantages of fixed-shift and rollover schedules

Comparison of the relative advantages and disadvantages of fixed-shift and rollover schedules, in terms of research evidence and practical considerations, points strongly to the value of operating the fixed-shift 14D/14N patterns rather than either of the 7/7 mid-tour rollover schedules[12,22]. A further suggestion, put forward by Gibbs et al., is that adoption of 14N schedules with shift changes at midnight and noon (a pattern traditionally worked by drill crews) would lower desynchrony load and facilitate adaptation during shore breaks[18].

A particular advantage of fixed-shift schedules is that they require only half as many circadian changes per year for each individual as compared with rollover schedules. This issue is potentially important in view of evidence suggesting that circadian disruption associated with long-term shift work increases risks of cardiovascular disease and other chronic health impairment[7,23,24]. Some North Sea companies have worked 14/14 fixed-shift schedules for many years; others have implemented this pattern more recently; however, among some offshore operators (particularly, smaller companies) the logistical difficulties involved are considered to be major obstacles.

Bright light interventions to facilitate circadian adjustment

The timing of exposure to light in relation to the sleep-wake cycle influences circadian adjustment. Thus, exposure to bright light at appropriate times in relation to an individual’s circadian cycle can facilitate adaptation by delaying or advancing the melatonin rhythm. A field trial of the effect of exposure to bright light for 30 minutes during the first four nights of a two-week night-shift tour, and the first four days of re-adaptation on return home, was carried out with Norwegian offshore workers[25]. The timing of the bright light was scheduled individually to bring about delay of the circadian rhythm; it had a modestly favorable effect on sleep during night-shift work, but the positive effect was particularly pronounced during re-adaptation back to a day-time cycle on return home. The authors suggest that offshore conditions facilitate adjustment to night-shift work within a few days, even without bright light; thus, its effect was relatively small offshore, but more marked during re-adaptation at home.

Overtime hours

Overtime hours in excess of the standard 84-hr week are worked by many offshore personnel[10,11], particularly those at more senior levels; thus, 60% of managers and 29% of supervisors reported total work hours in excess of 100 hrs per week[11]. The effects of these very long work hours have not been evaluated in the offshore work environment, but evidence from onshore studies suggests that impaired performance would be expected[14]; moreover, higher age and heavy workload (characteristic of many offshore managers) combine with extended work hours to give rise to performance decrements[2].

Three-week offshore tours

Whilst two-week tours are the norm for most offshore workers, some UK installations operate a 3-3 pattern (three weeks offshore, alternating with three weeks shore leave); however, there appears to have been only one attempt to assess whether these extended tours increase the risk of fatigue and human error[26]. In this small-scale study, data on sleep, subjective alertness, and workload were collected from day-shift personnel (N=55) on three occasions (start, middle, and end-of-shift) during each of four successive shifts. The effects of tour duration (2 weeks versus 3 weeks), and week-into-tour (first, second, or third) were evaluated across groups.

No clear evidence of adverse effects of a third week offshore was found, although there was a weak trend of reduced alertness across successive weeks of the 3-3 schedule. Moreover, in the analysis of survey data, satisfaction with three-week tours was significantly lower than for two-week tours, especially among personnel on production platforms. If extended tours continue to be used in the North Sea, there is a need for a more extensive evaluation of fatigue and performance impairment during the third week offshore.

Implications of research findings for ‘real-world’ operational risk

The research outlined in this review consistently demonstrates the adverse effects of offshore night work on measures of cognitive performance, particularly for ‘rollover’ schedules which involve mid-tour shift changes. However, the extent to which a decrement in performance, as assessed by standard tasks (for instance, reaction time or short-term memory), increases the ‘real-world’ risk of adverse operational outcomes resulting from human error cannot readily be determined; in other words, “There is no heuristic available to translate, for example, a 10% change in reaction time into some safety or health consequence” [27].

As a possible approach to linking performance on standard laboratory tasks to ‘real world’ outcomes, researchers have drawn attention to the fact that relatively moderate levels of sleep loss and fatigue impair performance on laboratory tasks to an extent equivalent to, or greater than, the impairment found for blood alcohol levels at or around the legal limit for driving in most Western countries[28,29]. In particular, Dawson et al. found that, after 17 hrs of sustained wakefulness, performance of psychomotor cognitive tasks declined to a level equivalent to the impairment observed at a blood alcohol level of .05%.

This finding has relevance to offshore workers, some of whom travel long distances to the heliport and may have been awake for up to 12 hrs before arriving offshore, already tired, to start a 12-hr night shift.[2] Dawson et al also found that, at a mean blood alcohol concentration of .10%, performance on a tracking task decreased by 11.6%; the magnitude of this decrement is similar to that found for the increase in RT among offshore workers immediately following a mid-tour shift change[12]. Thus, although laboratory tasks do not represent the full complexity of real-world information-processing and decision-making, performance decrements observed in experimental research should not be disregarded.

Individual risks; injury and illness offshore in relation to work hours

The safety and health of personnel employed on offshore installations, and the effective management of potential risks, are important issues for oil and gas companies operating in the North Sea. The demands of extended working hours and shift work (among other factors) may impact on rates of injury and illness experienced by offshore workers. A range of individual health and safety outcomes have been examined in relation to offshore work patterns; in particular, analyses of accident/injury data, and surveys of physical health complaints, psychosomatic problems and psychological distress among offshore workers, have been reported.

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[2] More than 50% of Norwegian offshore workers arriving offshore to work night shifts reported being awake for 10 hrs or more before starting their first night shift, and 33% for 12 hrs or more.

Accidents and injuries in relation to work hours offshore

Direct comparisons of accident/injury rates across days-into-tour or clock hours require information about exposure rates (quantified in terms of the number of man-hours worked in any particular time period), but relatively few studies of offshore injuries have had access to this information. Alternatively, it is sometimes possible to make a reasonable assumption that the exposure rate is constant across different time periods (e.g. across hours-into-shift). If the number of personnel at risk is not taken into account, the observed frequency of incidents will primarily reflect the number of personnel exposed at any particular time; for instance, a smaller number of incidents may occur during night shifts as compared with day shifts, but this does not necessarily imply a lower rate of incidents per man-hour worked.

Forbes[30] examined injury rates among drill crew in relation to days-into-tour, time-into-shift, and shift rotation pattern, taking exposure rates into account. Two groups were identified: Group A worked ‘rollover’ shift patterns with shift changes at 00.00 hrs and 12.00 hrs; Group B worked fixed-shift patterns changing shifts at 06.00 hrs and 18.00 hrs. The injury rate for Group A was almost three times higher than that for Group B; examination of injury patterns over time suggested that the mid-tour shift change partially accounted for this finding. Overall, there were more accidents during the first week than the second week; thus, there was no evidence in these data of cumulative fatigue effects over the two-week tour.

In an earlier study of offshore drill crew, injury rates were compared for two ‘rollover’ rotation patterns (7D/7N and 7N/7D)[31]. The results showed that injury rates were elevated on Day 1 of the tour if nights were worked during the first week, but on Days 6 and 8 if nights were worked during the second week. Thus, circadian disruption during the initial shifts of night work was associated with higher injury rates irrespective of whether the night shift week was the first or second week of the tour. There was no trend of increasing injury rates towards the end of 12-hr shifts. Discussing these findings in a wider context, the authors concluded that, although day-to-day changes in injury rates were affected by shift patterns, differences in safety policy and activity levels between different companies played a more important role.

In a more recent study (primarily intended to compare three-week and four-week leave periods), 481 incidents of physical injury (divided into medical-treatment cases and first-aid cases) were analyzed in relation to days-into-tour[1]. A significant increase in the number of incidents requiring first-aid treatment was found across the two-week tour. This finding could potentially be explained as an effect of cumulative fatigue; however, more serious injuries requiring medical treatment did not show a similar trend. As the authors note, it is difficult to explain why cumulative fatigue should impact on incidents requiring first-aid treatment but not on more severe medical-treatment incidents.

Large-scale industry data relating to offshore injuries (collected to meet government/industry reporting requirements) does not usually allow any direct estimate of exposure rates. In the absence of such information, an alternative strategy for analyzing injury data is to examine the ratio of severe injuries to more minor ones; in this type of analysis, the question addressed is 'If an injury occurs, what factors (e.g. time-into-shift, or days-into-tour) affect the severity of the injury?' Analyses of this kind (examining severe injuries in relation to 3+ day injuries) have been carried out using accident data bases from the UK Health and Safety Executive, and from multinational oil companies[32]. The main findings relevant to offshore working time can be summarized as follows:

Hours-into-shift. The proportion of severe injuries relative to 3+ day injuries was significantly higher for shifts of longer than 12 hrs than for normal 12-hr shifts. This pattern was particularly marked in the drilling area.

Day vs. night shifts. The distribution of injury severity differed significantly across day shifts and night shifts; night shifts showed higher rates of serious injuries relative to 3+ day injuries. This effect was independent of days-into-tour.

Days-into-tour. For tour durations longer than two weeks, the ratios of fatalities and severe injuries to 3+ day injuries increased very steeply, relative to tour durations of one and two weeks. Whilst this result could imply fatigue resulting from long tours, an alternative explanation is that three week tours are more likely to be operated on older installations with less rigorous safety procedures.

Analysis of sickbay consultation records can also provide information about offshore shift work and injuries. Thus, over a three-year period, higher overall consultation rates were found for day/night shift workers (all working 7N/7D rotation patterns) than for day workers[33]; moreover, the proportion of consultations made by the day/night shift workers attributable to injury (19.6%) rather than illness was higher than that for day-workers (11.5%). These findings are consistent with other evidence of higher injury rates during night-shift work.

Physical and psychological health among offshore personnel

The physical and, in particular, the psychological health of offshore workers has been widely investigated; research interest in this topic dates from the relatively early years of North Sea exploration[34-36], but more recent studies have also been reported[37-40]. These studies highlight the range of work-related stressors to which offshore personnel are exposed, and identify associations with physical and psychological health complaints. However, as the analyses are based on cross-sectional survey data, it is not possible to infer that the work environment plays a causal role in the health outcomes reported.

Moreover, it is important to note that offshore workers are required to meet higher medical standards than comparable onshore personnel. Thus, a priori, offshore workers would be expected to have better physical and mental health than their onshore counterparts. In offshore survey research, the role of long work hours and offshore shift patterns as risk factors for health impairment has been examined primarily in relation to sleep complaints and psychosomatic problems[41-43].

Offshore work hours in relation to sleep complaints

The quality and duration of sleep during offshore tours is an important issue, not only because poor sleep has adverse effects on day-to-day performance and alertness[44,45] but also because onshore research links chronic sleep deficits to long-term health impairment[46-48]. In the offshore environment, sleep quality is potentially impaired not only by circadian disruption associated with night work, but also by environmental factors (e.g. noise, shared cabins, poor air quality).

An extensive survey of sleep, health, and shift work was carried out on Norwegian installations in 1990 (N=1608)[41]. Sleep problems were found to vary with shift rotations but, in general, sleep was more favorable in the second, as compared with the first, week offshore, suggesting progressive adaptation to offshore conditions. Use of sleep medication was largely restricted to the initial shifts of night work, particularly following a mid-tour shift change, and was reported by relatively few individuals. Noise and cabin-sharing were the most frequently-reported environmental causes of sleep disturbance in this survey. At that time, the majority of Norwegian offshore personnel shared cabins; since then, however, arrangements that allow sole occupancy of a cabin during sleep hours have been widely introduced. Currently, less than 10% of Norwegian offshore workers report that they share cabins ‘mostly’ or ‘very often’, and only 8.4% of personnel ‘rarely’ or ‘hardly ever’ sleep well offshore[10].

Direct comparison of sleep patterns reported by onshore and offshore oil industry personnel throws further light on factors affecting the sleep of day/night shift workers[42,43]. Both these studies showed that the sleep of offshore night-shift workers was more favorable than that of their onshore counterparts. Further analyses demonstrated that factors, such as age and smoking, that adversely affect night-shift sleep among onshore workers, did not act as risk factors for poor sleep offshore[43]. Sleeping in cabins without windows (and thus avoiding light exposure at inappropriate times)[18], and the 'round-the-clock' operating pattern of offshore installations, may serve to facilitate circadian adjustment of sleep patterns to night-shift work offshore.

In a study carried out in the Campos Basin, Brazil, 20.2% of the day/night shift workers reported their sleep to be 'bad' or 'very bad', as compared with only 1.2% of day workers[49]. For 'fragmented sleep', the figures were 45.2% and 16.3%, respectively. In addition, the proportion of shift workers reporting sleep durations of less than 6 hrs (the duration widely regarded as a minimum sleep requirement) was 44%; the corresponding proportion for day workers was 16%.

Sleep duration and overtime hours offshore

52% of offshore day-shift personnel (particularly managers and supervisors) report working significantly longer hours than the standard 84 hrs per week[11]. In further analyses, sleep duration among day-workers (N=772) was examined in relation to reported work hours (with control for age); longer work hours were significantly and linearly associated with shorter sleep durations. For those reporting no overtime beyond the 84 hr offshore week, mean sleep duration was 7.00 hrs, but for those reporting 20+ hrs overtime (i.e. more than 104 hrs per week), mean sleep duration was 6.03 hrs. Thus, high levels of overtime offshore not only result in unduly long work hours, they also impact adversely on sleep hours.

Offshore shift work and psychosomatic problems

The most frequently reported psychosomatic complaints in the 1990 survey of Norwegian offshore workers[41] were headaches, stomach problems, and muscular tension, but the incidence of these complaints varied across shift patterns and occupational groups. Stomach problems were particularly associated with rotating day/night shift work. A further study of psychosomatic problems offshore evaluated the independent effects of shift pattern and occupational group[39]. The results showed a clear pattern: day/night shift work, as compared with day work, was associated with sleep problems and gastric problems, while the incidence of headaches, musculoskeletal problems, injuries, and psychological symptoms differed across job types.

Musculoskeletal problems

Musculoskeletal disorders (MSD) are widely reported by offshore workers; cramped work areas, heavy physical work, frequent stair-climbing, poor ergonomic design of workplaces, and psychosocial work stress generally, are all potential causes of MSD. In a recent survey of Chinese offshore workers, 56% reported experiencing at least one MSD complaint over the previous year; physical environment stressors and ergonomic problems were significant predictors of MSD complaints[37]. Similarly, in the UK sector, 46% of offshore workers surveyed (N=1462) reported at least one MSD problem[11].

However, although long work hours play a role in MSD among onshore workers[50,51], and similar effects are likely on offshore installations (especially among those doing physically heavy work , or working in cramped postures), this issue does not appear to have been investigated in the North Sea workforce.

Psychological distress

The extent to which offshore workers show elevated levels of anxiety and other symptoms of psychological distress, relative to comparable onshore workers, is unclear; a review of relevant findings[52] revealed that high levels of anxiety (especially among personnel at senior levels) were found in some, but not all, studies. However, the studies reviewed did not take into account the overtime hours worked; some evidence suggests that elevated levels of anxiety are associated with hours in excess of the standard 84 hrs per week[11]. This result was largely due to the high anxiety among offshore personnel (primarily managers and supervisors) who reported working more than 100 hrs per week. However, whether the long work hours represent a cause or an effect of high anxiety cannot be determined in cross-sectional survey data.

Overview of injury and illness risks in relation to offshore working time

It is evident from the material reviewed above that some aspects of work schedules impact unfavorably on a wide range of health and safety outcomes. In particular, night-shift work (especially the 7N/7D rotation pattern) disrupts normal circadian rhythms, with consequent adverse effects on sleep duration and quality, on eating patterns, and on gastric and digestive problems. Poor sleep quality and accumulated sleep deficits in turn give rise to fatigue, and to impairment of subjective alertness and performance, thereby increasing the likelihood of error, and consequently the risk of accidents and injuries. While night-shift work cannot be eliminated on installations operating continuous production and drilling processes, research findings point clearly to the importance of implementing shift patterns which most effectively facilitate circadian adaptation, reduce sleep disturbance, lessen performance impairment, and promote individual well-being.

Long day-work hours offshore are also a potential source of concern. A recent review of research into extended work shifts and overtime in onshore work settings identifies adverse effects on illness, injury, health behavior, and cognitive function[2]. However, adverse effects are not always observed; for instance, Persson et al reported that a work schedule of 84-hrs per week (alternating with a one-week break) did not give rise to performance impairment, elevated fatigue, or sleepiness among onshore construction workers[15]. Similarly, in the offshore environment, there appears to be little clear or consistent evidence of cumulative fatigue across two weeks of 12-hr day shifts, although this issue cannot be regarded as resolved. However, overtime work offshore (especially when the work week exceeded 100 hrs) was associated with shorter sleep duration and with higher anxiety.

Areas in which further research is needed

The material presented here reviews existing research findings relevant to offshore working patterns, and their impact on operational and individual risks on North Sea installations. However, there are other important factors that potentially affect operational and individual risk offshore, about which little is currently known. In particular, individual and environmental characteristics may interact with long work hours and shift patterns to mitigate or accentuate effects on performance and health, but these topics remain to be investigated. Several research areas of particular importance are outlined in the following sections.

Age and offshore working time patterns

The oil and gas industry has an ageing workforce. The average age of Norwegian petroleum workers in 2002 was 45 yrs[53], and more than 20% of a large sample of Norwegian offshore workers surveyed in 2001 were in the 50+ years age range[54]. The corresponding proportion in the UK offshore sector was 12% in 1996, while 70% of the survey sample were in the 30-49 yrs age range[11]. The higher proportion of older personnel in the Norwegian offshore workforce could be due to the more generous work/leave schedules operated in the Norwegian sector, as compared with the UK, sector, but wider differences in labor market conditions may also play a part. In both sectors, the age profile of the offshore workforce, which has continued to increase in more recent years, is a matter of concern to the industry, particularly in view of the relatively high proportion of personnel working day/night shift rotations.

Research findings indicate that older age is associated with increased difficulty in adapting to day/night shift work, reduced performance on cognitive tasks (particularly those involving attention and/or memory), impaired sleep quality, reduced capacity for physical work, higher rates of occupational injury/fatality, poorer health, and more frequent sickness absence[55-59]. Moreover, duration of exposure to shift work contributes (over and above the effects of age) to impaired performance and sleep[42,60].

These issues are important in a mature industry employing an ageing workforce, but few studies have investigated the role of ageing in relation to offshore working time, in spite of the demanding shift-rotation patterns, extended 12-hr shift durations, and frequent overtime hours to which workers are exposed. However, some evidence suggests that the offshore environment may partially mitigate the adverse effects of age on adaptation to night-shift work found onshore. Thus, offshore, older workers showed relatively little impairment of sleep during night-shift work as compared with day-shift work, and as compared with their sleep during periods of leave; in contrast, among onshore oil industry personnel, night-shift sleep among older workers showed significant impairment relative to that of younger co-workers[43].

Further research is required to understand the effects of ageing on the performance and well-being of offshore workers, and to identify particular work patterns, tasks, and environments that may place older workers at disproportionate risk. For instance, it is possible that mid-tour shift rotation (especially the 7N/7D schedule) has a particularly unfavorable impact on cognitive functioning and alertness among older workers. Similarly, older workers, irrespective of shift pattern, may be more vulnerable to the effects of cumulative fatigue over the course of a two-week offshore tour.

Management personnel (particularly the Offshore Installation Manager) carry heavy responsibilities for the safe operation of the installation and the well-being of personnel on board. These senior personnel also tend to be in the older age groups offshore; however, little is known about how age, heavy workload and, in some cases, very long work hours, combine to affect fatigue, alertness, decision-making processes, and health risks in this occupational group. A recent article[61] discussing 'work ability' in relation to older workers in 'high-demand jobs' (a category that would include offshore management) is particularly relevant in this context.

In view of the changing demographic profile of North Sea workers, the long hours and night-shift work required offshore, and the need to retain experienced older personnel in the workforce, the effects of ageing on risks to installation safety and individual well-being, is a topic much in need of research attention.

Exposure to physical and psychosocial environment stressors

A further topic which has received little research attention is the combined effect of offshore working time patterns and environmental stressors. Potential physical stressors offshore include noise, poor air quality, vibration, hazardous chemicals, extreme temperatures, and cramped workspace. The severity of these stressors depends on installation design and construction, but also on occupation. For instance, offshore drill-crew personnel are exposed to multiple physical stressors, round-the-clock operations, and heavy physical work. Wind and sea conditions also play an important role in relation to the offshore physical environment, especially in some of the more inhospitable areas of the North Sea; in particular, on FPSO's, rough seas can produce uncomfortable vessel motion, and consequent sea-sickness among the crew.

In view of the wide range of potential physical stressors offshore, it is important to know to what extent exposure to an adverse physical environment may result in decrements to performance (over and above those associated with long hours and day/night shift rotation offshore), and possible long-term impairment of health. Currently, there appear to be no research studies carried out offshore to evaluate such effects. However, some onshore research has examined the joint effects of work patterns and exposure to physical environment stressors[62-64].

Findings from these onshore studies suggest that stressors may act additively, or combine to produce multiplicative effects on health and safety outcomes. For instance, exposure to combined temporal stressors (shift work and long hours) and physical stressors (noise and hazardous substances) was found to have significant effects on blood pressure and cortisol, which were not observed for either of the stressors separately; however, cognitive performance and mood outcomes did not show similar effects[64]. In an earlier study, occupational noise combined with night-shift work significantly increased the risk of high blood pressure relative to noise alone[62].

Onshore research also demonstrates that stressors associated with the psychosocial work environment (e.g. heavy workload, low social support, low control over work tasks) may affect the magnitude of effects on performance, mood, and health outcomes associated with long work hours, shift patterns, and other temporal work characteristics[63,65,66]. In this respect, also, research specific to the offshore environment is lacking; whilst the psychosocial work environment offshore has been widely studied in relation to mental and physical health outcomes[34,52,67], the extent to which factors such as social support, supervisory style, task clarity, and team cohesion, act in combination with offshore shift rotation patterns and long work hours to mitigate or accentuate effects on performance and well-being has not been examined.

Effects of long work hours among day-workers offshore

Whilst the effects of working hours among offshore day/night shift workers have been extensively studied, much less information is available about the effects of long hours on day-workers offshore. In particular, concerns have been raised about two groups; offshore management personnel, many of whom work very long hours, and specialists and other contractors who move from one installation to another, often with extended and unpredictable work schedules.

Offshore managers and other senior personnel. Offshore managers have overall responsibility for the safe operation of offshore installations, and the productivity and well-being of all personnel onboard. Therefore, their ability to make decisions, to monitor day-to-day changes in production/drilling activities, to process, interpret, and act on information appropriately, and to respond speedily and effectively to emergency situations, is of particular importance. However, the working time of offshore managers is not restricted by EU legislation, and (as noted earlier in this report) these personnel often chose to work very long hours. Little is known about how such extended work hours affect offshore managers' cognitive abilities, subjective alertness, mood, and long-term health, although evidence from onshore industry suggests that long hours worked over an extended period are associated with performance decrements[14]. Data collection methods similar to those developed to study the effects of shift rotation patterns offshore could be used to assess patterns of performance, sleep quality, and mood among managers over a sequence of extended day-shifts.

Specialist contractors. Some offshore personnel working for specialist agencies (particularly those involved in drilling and exploration) routinely move from one installation to another carrying out specific tasks not covered by the regular crew. These personnel tend to have no regular work/leave cycle; rather, they undertake successive jobs as required by their employer. In the past, this arrangement often led to excessively long work hours; however, the UK oil/gas industry has recently introduced an 'offshore passport' scheme (the

'Vantage System') which tracks trip histories, competencies, and training. It provides a way for operating companies to check that the amount of time spent offshore, with the aim of limiting excessive work hours. However, even when working time is monitored, the unpredictability of the schedules worked may still cause problems for the specialists concerned, and for their spouses and families. Thus, the work patterns to which these particular groups of offshore personnel are exposed merits more detailed examination in relation to health and safety outcomes than it has yet received.

The impact of work schedules on the health and safety of women offshore

Women make up only a small minority of offshore personnel in the UK sector (<5%), although they form a higher proportion of workers in the Norwegian sector[52,54]. Over recent decades, opportunities for women to undertake 'non-traditional' work have increased, and it is likely that the women will form a higher proportion of the offshore workforce in the future. Therefore, it is important to understand the effects on women of offshore work patterns and long work hours, particularly in the light of evidence from onshore studies linking shift work to adverse pregnancy outcomes and other aspects of reproductive dysfunction[68].

It is also important to study the social and psychological impact on the spouses and children of women working offshore. When the male partner is the one working offshore, evidence suggests that the spouses and families involved are generally able to adapt to the emotional and practical demands that the lifestyle imposes[69]. However, little is known about adjustment among families of women working offshore.

Longitudinal studies of health impact of offshore work

To date, there have been no long-term evaluations of the health impact of offshore work, although the characteristics of the North Sea environment (e.g. remoteness, harsh weather, living in close proximity to work colleagues, reliance on helicopter travel, and constrained living accommodation) coupled with long work hours and demanding shift schedules may have health effects over and above those of onshore employment. The issue of possible long-term health effects is particularly important in view of the current interest in encouraging workers to remain in offshore employment for more years and/or to older ages than has traditionally been customary. Ideally, such studies would include continued monitoring of those who choose to retire early from offshore work, and those who are excluded for medical reasons, as well as those who continue work offshore to age 60 years or older.

Work in both the UK and the Norwegian offshore sectors requires routine medical examinations (currently, in the UK sector, every two years); thus, there is a large amount of medical information on individual offshore workers that could (together with data from regularly administered surveys) potentially form the basis of such a study. Whilst research of this kind is inevitably vulnerable to attrition of the sample over time, the offshore environment could provide an unusually favourable situation in which to track long-term changes in health in relation to work demands, in addition to providing specific information about the effects of offshore work hours and employment conditions more generally.

Dissemination of offshore research

The material reviewed in this paper shows that, at a time of continuing change in the offshore industry, there is a significant agenda of research into the effects of working time patterns offshore that remains to be undertaken. Such research merits the attention of medical, psychological, and physiological researchers. However, it is also important that research findings are made readily accessible to the offshore industry, and that a continuing dialogue is maintained between researchers, health and safety professionals, trade union representatives, and industry managers, with the shared aim promoting health and safety in the offshore environment.

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