Risk factors and risk reduction strategies associated with night work with the focus on extended work periods and work time arrangement within the petroleum industry in Norway

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FOREWORD

The work time regulations in the petroleum industry of Norway allow the use of long work hours and extended work periods in offshore operations. Similar arrangements are accepted for commuting workers in onshore construction and commissioning projects. In addition to the use of shift work and long weekly work hours, overtime in the same shift systems are common offshore and onshore when the project deadlines approach.

There is growing evidence that long work hours and shift work are related to impaired health and increased occupational accidents (Härmä, 2006; Van der Hulst, 2003). Night work and shift work are related to a wide range of health effects, the evidence for the risk of cardiovascular morbidity being the strongest. Insufficient or poor sleep, related to insufficient recovery, can be a common pathway from long work hours and shift work to increased cardiovascular and other risks. The regulation of overtime and excessive workhours, the use of individual worktime control, and sleep-promoting principles into shift rotation are among the most promising ways to alleviate the health effects of shift work (Härmä, 2006).

Related to the North Sea, the questionnaire analysis of Petroleum Safety Authority (PSA) showed that although the most serious injuries take place during the day shift, there is a significant increase in the frequency of injuries during night shift (Lauridsen, Bjerkebaek, Danielsen, & Loland, 2006). It is also generally acknowledged that poor sleep and operational fatigue are risk factors for occupational and operational accidents. For example, based on a qualitative analysis of the reported accidents at sea, in 86% of the cases, poor sleep has been cited as one of the causal factors (Phillips, 2000).

This review aims at the detection of risk factors and risk reduction strategies associated with night work with the focus on extended work periods and work time arrangement in the petroleum industry in Norway. The review was requested by the Petroleum Safety Authority (PSA), Norway, in August 2006, and was handed over to the PSA at the end of February 2007. The comments of PSA from the first version of the report are corporated in the text.

Authors

1. INTRODUCTION

1.1. Objectives

This review aims at the detection of risk factors and risk reduction strategies associated with night work with the focus on extended work periods and work time arrangement within the petroleum industry in Norway.

More specifically, the report aims

1. at giving an overview of current knowledge on the effects of shift work and extended work periods on sleep and sleepiness, performance and operational risk, health and the risk for injury
2. at giving an overview of the risk reduction strategies associated with shift work and extended work periods related to shift scheduling, individual coping strategies and occupational health care
3. at discussing possible particular risks related to work time arrangements within the Petroleum industry in Norway, and at giving recommendations for implementation of current knowledge, as well as strategies for further research within the area.

1.2. Literature search

The review covers both general effects of shift work and long work hours as well as more specifically, the literature related to the use of extended work periods common in the Petroleum industry of the Northern sea. The review tries to sketch an overall picture of the risk factors and risk reduction strategies of shift work and long work hours and, in addition, reviews in more detail the literature on the health and safety issues of extended work periods (the use of extended periods of long work shifts followed by similar periods of compensatory leave). To identify relevant sources of information for the latter part of the review, a number of searches were performed within the on-line databases including PUBMED, EBSCO (Psychinfo & Academic Search Premier), CISDOC (ILO), Safety Science and Risk (Health and Safety Science Abstracts (CSA), and Google-Scholar. Additional searches were made manually from a number of reports and essential reviews. The keywords used to identify publications relating to the specific questions of the report were the following: "extended work periods" or "extended work period" or "extended work shifts" or "extended work hours" or "extended working schedules" or "long work shifts" or "long work hours" or "twelve-hour-shift" or "sixteen-hour-shift" or "12-hour-shift " or "16-hour-shift" or "compressed work week" or "compressed working week" or "extended hours work or "overtime work". The search in Google-Scholar was limited to studies focusing on the petroleum industry. In Psycinfo the searches were restricted to peer-reviewed journals, and in Academic Search Premier the search was limited to primary source publications.

1.3. Authors

The authors of this review are a group of experts working in the Finnish Institute of Occupational Health, Centre of Expertise on Human Factors at Work. The authors (and sphere of competence in the report) are Professor, Director of the Centre of Expertise Mikko Härmä, MD, PhD (sleep/wakefulness and coordination); Adjunct Professor, neurologist Christer Hublin, MD, PhD, Brain Work Research Centre (sleep medicine, occupational health care); specialized researcher Sampsa Puttonen, PhD, Brain Work Research Centre (health); Adjunct Professor, senior researcher Simo Salminen, PhD, The Unit of Accident Research (accidents and risk for injury); and Adjunct Professor, senior researcher Mikael Sallinen, PhD, Brain Work Research Centre (performance and operational risk).

1.4. Working hour arrangements in the petroleum industry of Norway

1.4.1. Work time regulations

Work hours in Norway are generally regulated by the work environment act. Some sections in the work environment act are substituted by requirements given in the framework regulation for the offshore petroleum industry. For instance the night work requirements in the work environment act don’t apply to the offshore industry.

The regulations generally allow the employers and unions relatively wide frames for making agreements on work time arrangements. The main restrictions for the work time agreements both on- and offshore are given in the work environment act of Norway, section 10-2. Work hours shall be arranged in such a way that employees are not exposed to adverse physical or mental strain, and that they shall be able to observe safety considerations. This means that both the parties and the authorities have to assess whether a specific work time arrangement is safe and prudent both with respect to safety and health effects. Such assessments shall be based on current knowledge on different risk factors, effects of interventions on exposure and outcomes etc.

1.4.1.1. Work time regulation and agreements offshore

The current worktime regulations for the offshore industry define the following limitations:

Ordinary work hours

- shall not exceed twelve hours per day (24-hour period) and 36 hours a week in average over a period of maximum one year, i.e., 1877 hours a year

Travel time and work hours

- the time used to travel to and from the workplace at the beginning or the end of each period of work or stay shall not be regarded as work hours

Rest breaks

- resting breaks shall be of duration of at least one hour included in the 12 hour work period

Overtime

- total work hours, including overtime, shall not exceed 16 hours per day (24-hour period). The overtime shall not exceed 200 hours (300 hours by agreement) in a 52 week period.

Periods of stay

- shall not exceed 14 days. In particular cases the employer may extend the period of stay by up to seven days

Off-duty periods and time off

- employees shall have a consecutive off-duty period of at least eight hours between two work periods. The off-duty time between two periods of stay shall have a consecutive duration of at least one third of the latest completed period of stay.

The regulations related to the ordinary work hours, overtime and the length of the off-duty period between two work periods do not apply to employees in senior or independent positions.

1.4.1.2 Work time regulation and agreements onshore

The framework for working hours regulations on land are found in the Working Environment Act chapter 10. PSA and The Labor Inspection have also made guidelines within the frames of the law. There is a difference between permissions given by the Authority and the trade unions.

Permits given by PSA:

12-9 rotation

- 12 days of work
- 9 days off
- 10 (effective) hours of work per day
- Sundays off
- the maximum weekly working hours are 60
- the average weekly working hours are 36,6
- a working day shall not exceed 10 hours
- a working week shall not exceed 60 hours
- the average weekly working hours shall not exceed 40 hours
- lunch breaks, coffee breaks etc. are not regarded as working hours
- work between 2100 and 0600 is night work and shall generally not be performed
- work shall generally not be performed on Sundays or public holidays
- an off-duty period of at least 11 hours is required between two working periods
- a continuous off-duty period of at least 35 hours a week is required

Permits given by the trade unions:

14-21 ”Offshore arrangement”

- 14 days of work
- 21 days off
- 12 (11 effective) hours of work per day
- no Sundays off
- no overtime and no work at night (at the end of deadlines night work is used in some extend with permit from unions)

- the maximum weekly working hours are 84
- the average weekly working hours are 32,8
- an off-duty period of at least 8 hours is required between two working periods

Melkøya and Nyhamna

- a total of 20000 employees has been working inside each site since these projects were started
- at least 3000 employees inside each plant work simultaneously in long periods
- most employees work in 14-21 rotations
- very few employees work in 12-9 rotations
- up to 3000 employees live in barrack-camps or on hired ships
- 2000-2500 foreigners are usually on-site at the same time

1.4.2. Shift systems

The use of 12-hour shifts for extended work periods in both offshore and onshore work of the petroleum industry is allowed by the work time regulations of Norway. In addition to the 86 weekly work hours of hours, overtime and 16-hour work shifts are common according to a recent PSA questionnaire (Lauridsen et al., 2006). This means that 18% of the offshore workers had worked more than 20 hours overtime and 8% more than 30 hours overtime on their last trip offshore. Most employees have agreements specifying that the ordinary work hours are 1485 for one year (2 weeks on 4 weeks off). Some agreements, however, say that they should be accessible for a period of 6 weeks, ready to go offshore on a short notice for up to 21 work days but no more than 14 days for one period stay.

Some of the staff work offshore for only a part of the year, for instance, the maintenance and construction workers during construction projects and revision stops. These employees carry out the major part of their work onshore, i.e. in shipyards or mechanical industry. They are normally not covered by the offshore work time agreements limiting work hours to 1485 in a year. While working offshore they normally work a 14 day shift period with shorter off-duty periods and increased use of overtime.

Concerning the crew at mobile drilling units that work both on the Norwegian continental shelf (NCS) and in other countries, the work hours performed aboard do not count, but the maximum limits for the ordinary work hours are scaled to the duration of work on the NCS.

Based on the last PSA questionnaire (Lauridsen, et al., 2006), the following shift arrangements were used in Norwegian shelf:

- day work (42.9%)
- variable shift arrangements (21.6%)
- a rotating shift system with fourteen 12 hour night or day shifts every second period followed by a compensatory leave (three or four weeks) (14N/14D, 15.5%)
- a rotating shift system with seven 12 hour night shifts and seven 12 hour day shifts followed by a compensatory leave (three or four weeks) (7N-7D, 12.5%)
- a rotating shift system with seven 12 hour day shifts and seven 12 hour night shifts followed by a compensatory leave (three or four weeks) (7D-7N, 5.1%)
- permanent night work (2.4%)

1.5. Definitions and abbreviations

BAC	Blood alcohol concentration
BMI	Body mass index
CHD	Coronary heart disease
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders (4th vers.)
EEG	Electroencephalography
EOG	Electro-oculography
Extended work periods	Extended periods (1 or more weeks) of long work shifts followed by similar periods of compensatory leave
Extended work shifts	Shifts longer than 8 hours
FDA	Food and Drug Administration (U.S.)
FIOH	Finnish Institute of Occupational Health
GABA	Gamma-aminobutyric acid

GHQ	General Health Questionnaire
HDL	High density lipoprotein
LDL	Low density lipoprotein
Long work hours	May include overtime, extended work shifts or extended work periods
NCS	Norwegian continental shelf
NIOSH	National Institute for Occupational Safety and Health (U.S.)
Occupational injury	Unexpected event causing physical harm to the worker
OR	Odds ratio
Overtime	Work hours exceeding the contracted work hours
PSA	Petroleum Safety Authority Norway
Shift work	An arrangement of work hours that uses two or more teams to cover the time needed for production
WHR	Waist-to-hip ratio
Work stress	Refers to the potentially harmful combinations of the conceptualized psychosocial factors at work.

2. SHIFT WORK AND EXTENDED WORK PERIODS: EFFECTS ON HEALTH, PERFORMANCE AND SAFETY

2.1. Sleep and sleepiness

2.1.1. Shift work

Shift work is related to a higher risk for sleep complaints, gastrointestinal and cardiovascular diseases (Åkerstedt, 2003; Härmä, 2006; Knutsson, 2003). The disturbances in sleep-wakefulness are probably the best acknowledged health problems of shift work. Disturbed sleep, which itself is a major health risk of shift work, may be an important pathway for the long-term health effects of night and shift work. Prospective epidemiological studies among normal population and shift workers show that disturbed or shortened sleep predicts not only sickness absence, work-related stress and burn-out but also many diseases too: obesity and type II diabetes, coronary heart disease and brain infarctions, musculo-skeletal diseases, depression, and minor psychiatric problems (Åkerstedt, 2006; Nilsson, Roost, Engstrom, Hedblad, & Berglund, 2004; Patel, Malhotra, White, Gottlieb, & Hu, 2006). However, sleep can, but need not be the only pathway between workhours, the psychosocial work environment, and health.

2.1.1.1. Shift work sleep disorder

According to DSM-IV clinical criteria, 10% of night and rotating shift workers have what is called the shift-work sleep disorder (Drake, Roehrs, Richardson, Walsh, & Roth, 2004). However, it is well known that the prevalence of excessive sleepiness during work (showing sleep intrusions) is around 25%, and those with reduced alertness constitute an additional 50%. So, a conservative estimate of the proportion of shift workers with severely reduced sleep or alertness lies somewhere above 50% (Åkerstedt, 2005). Sleep problems due to shift work tend to increase with aging (Härmä, Tenkanen, Sjöblom, Alikoski, & Heinsalmi, 1998; Moneta, Leclerc, Chastang, Tran, & Goldberg, 1996; Rosa, Härmä, Pulli, Mulder, & Nasman, 1996). The percentage of the working population that fails to adjust to shift work is usually estimated as being of the order 10-20%. Many shift workers change from shift work to day work at different stages of the work career. Due to this self-selection and "the healthy worker" effect, the occurrence of sleep complaints among shift workers is often lower than expected and may not increase after the age of about 50 years (Marquie & Foret, 1999).

2.1.1.2. Factors influencing sleep-wakefulness in shift work

The variation of sleep-wakefulness in shift work is influenced by several factors (Figure 1). As indicated by different models explaining the variation of sleep and sleepiness, the major factors predicting sleep (sleep length, sleep latency, sleep structure) and sleepiness (sleep propensity and sleepiness) at work are related to the *circadian variation* of body functions, *time spent awake*, and *sleep recovery*, (Åkerstedt & Folkard, 1997 among others). Sleepiness immediately after waking up, the so called "*sleep inertia*" is a separate factor increasing sleepiness significantly up to some 30 minutes after waking up. In addition to the general circadian and homeostatic factors mentioned above, *work demands* influence the expression of sleepiness during a work shift. *Individual factors* related to aging, morningness-eveningness, living habits and social and personal factors modify the circadian variation of body functions, and may influence sleep recovery or even work demands (Härmä, 1993, 1995).

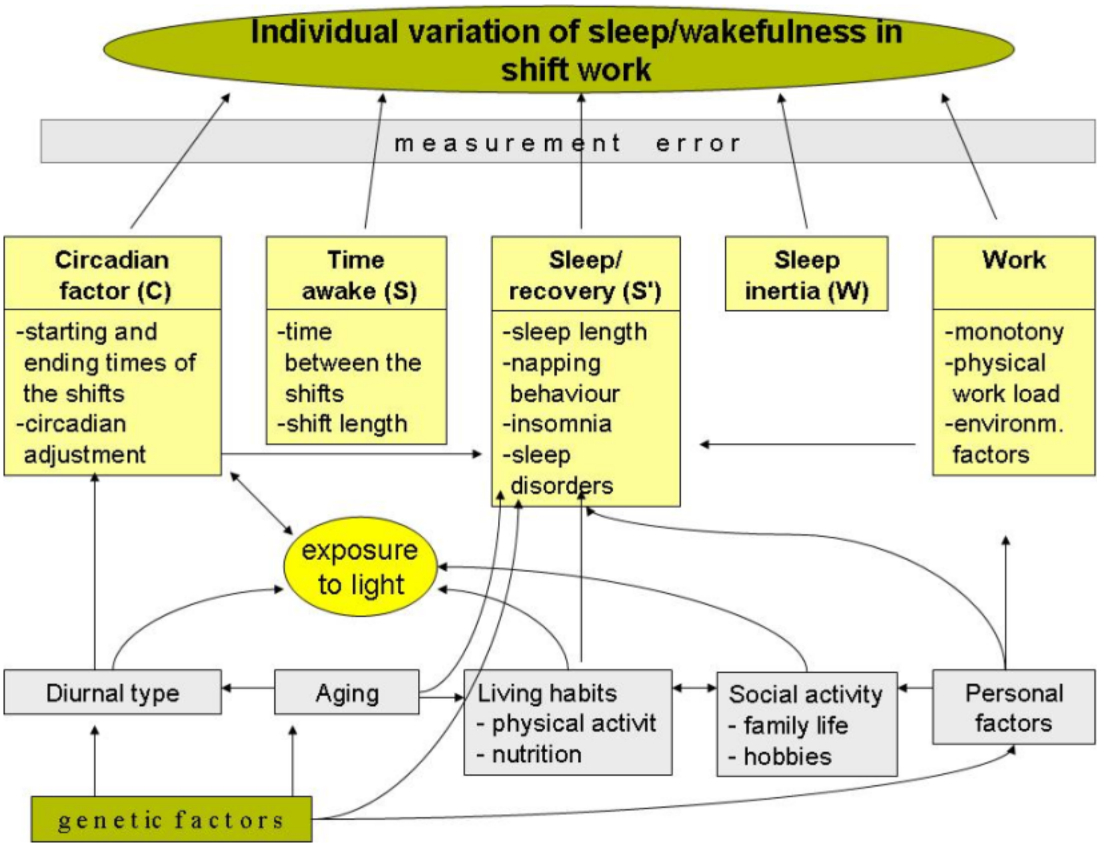

Figure 1. Factors influencing the variation of sleep-wakefulness in shift work.

Circadian rhythm

The circadian rhythm in sleep-wakefulness in shift work is well acknowledged. Night sleep before the early morning shifts and day sleep after night shifts are normally curtailed by some two hours (Åkerstedt, 2005; Sallinen et al., 2003). The sleep loss involves mainly Stage 2 and rapid eye movement sleep. Similarly, sleepiness is most frequent during the night and early morning shifts (Åkerstedt, 1998b; Härmä, Sallinen, Ranta, Mutanen, & Müller, 2002). For example, severe sleepiness was reported in 49% of the night shifts and in 20% of the early morning shifts in a large group of train drivers (Härmä et al., 2002). During the day and evening shifts, severe sleepiness was rare. The odds ratios showed that the risk for severe sleepiness was 6-14 times higher in the night shift and about twice as high in the morning shift compared with the day shift.

Time spent awake

Besides the time of the day, both sleep and sleepiness are modified by time spent awake. Basically, sleepiness at work grows exponentially by the total time spent awake, while the time of the day simultaneously influences sleepiness by a sinusoidal pattern (Folkard, Lombardi, & Tucker, 2005). Since time spent awake is much shorter during the day and even evening shifts compared with the first night shift, sleepiness is increased during the first night at work in addition to the circadian influences on sleepiness. During the first night shift, sleepiness may thus be higher than during the second or third night shift due to the longer time spent awake before the night shift. About 50-80% of shift workers nap before the first night shift (Härmä, Knauth, & Ilmarinen, 1989; Sallinen et al., 2003). The option to nap before or during the night shift is critical for the change in sleepiness during the night shift. Napping before and during the night shifts thus improves alertness and performance considerably (e.g., Sallinen, Härmä, Åkerstedt, Rosa, & Lillqvist, 1998; Sallinen et al., 2003).

Shift systems vary significantly in relation to how they influence the time spent awake and sleep recovery in relation with different shifts. First, too short an interval between an evening and morning shifts (the co called "quick returns) decreases sleep length and may make sleep recovery insufficient. In general, the occurrence of severe sleepiness during the shifts is directly related with the length of the night sleep (Härmä et al., 2002). The starting time of the morning shift is especially critical. Each hour delay in the starting time of the morning shift is related with a 40-50 minute extension in the main sleep length (Rosa et al., 1996; Sallinen et al., 2003). Human beings need about 8 hours of sleep per day. If the time between the shifts at night is less or even close to that period, it is obvious that full recovery is not possible.

Secondly, too short time-off interval and/or an early starting time of a night shift makes napping before the night shift more difficult. Especially the 12 hour night shifts start very early, normally at 8 p.m. Based on a recent study, the later the starting time of a night shift, the greater the likelihood for the napping (Sallinen et al., 2003). Finally, the length of the shift is directly related to time spent awake. The existing literature on the relationship of shift length with fatigue is somewhat inconsistent, a number of studies supporting (Härmä et al., 2002; Rosa, 1991; Rosa, Colligan, & Lewis, 1989; Rosa, Wheeler, & Colligan, 1985) and a number of studies rejecting (Lowden, Kecklund, Axelsson, & Åkerstedt, 1998) the hypothesis that long work shifts increase sleepiness.

Work demands

Work demands and tasks may modify sleepiness by variation in mental and physical work load or monotony, stress, environmental and ergonomical factors (different temperatures, vibration, noise, work positions). In our recent study, the interactions of sleep deprivation and work demands were studied during 12-hour shifts different from each other in terms of the amount of preceding night sleep (11:00 p.m. - 06:30 a.m. or 2:30 a.m. - 6:30 a.m.) and work pace (slow or fast). Based on objective sleepiness with a continuous EEG/EOG recording during the work periods, the results suggested that monotonous work tasks increased sleepiness during the day shift as much as the moderate sleep deprivation (Sallinen et al., 2004). Psychosocial stress, measured by the Karasek 's model, also correlates strongly with sleep and sleepiness at work (Kalimo, Tenkanen, Härmä, Poppius, & Heinsalmi, 2000). Concerning the environmental factors, higher temperature increases sleepiness at work while exposure to bright light decreases it. For example, in the classical study by (Mackworth, 1950) among air traffic controllers, performance in the task started to decrease during the second hour at work and the decrease was higher at 25, 31 and 36 °C compared with 21°C.

Individual differences

The manifestation of sleep and sleepiness in abnormal workhours is highly individual (Härmä, 1995). The percentage of the working population that fails to adjust to shift work is usually estimated as being approximately 10–20%. Aging is one of the major factors influencing both the circadian adjustment to night work (Härmä, Hakola, Åkerstedt, & Laitinen, 1994) and the homeostatic functions of sleep (Åkerstedt & Torsvall, 1981). Aging is related to a slower circadian adjustment during consecutive nightshifts, as well as to shorter sleep after nightshifts (Åkerstedt, 2005; Sallinen et al., 2003). Epidemiologic studies indicate that insomnia due to shift work increases with age (Härmä et al., 1998; Moneta et al., 1996). However, older shift workers do not complain about more sleepiness than their younger colleagues (Bonnefond et al., 2006; Rosa et al., 1996). Diurnal type, personality, and different coping mechanisms (like physical activity) modify the effects of night and shift work on sleep and fatigue (Härmä, 1995; Härmä, Ilmarinen, Knauth, Rutenfranz, & Hänninen, 1988a). For example, it is more difficult for morning types, with an earlier circadian phase and sleep–wake rhythm, to phase delay their circadian rhythms during consecutive night shifts than it is for evening types (Härmä, 1995). In a controlled intervention study, regular physical activity improved sleep in general, and alertness especially, during night shifts among nurses in an irregular shift system (Härmä et al., 1988a; Härmä, Ilmarinen, Knauth, Rutenfranz, & Hänninen, 1988b).

To sum up, about 10% of night and rotating shift workers have a shift work sleep disorder, characterized by frequent insomnia and severe sleepiness at work. The major factors influencing sleep length and quality, as well as sleepiness in shift work are the circadian variation of body functions, time spent awake, earlier sleep recovery, work demands and different individual factors like aging and morningness-eveningness. About 10-20% of the working population fail to adjust to shift work.

2.1.2. Long work hours

2.1.2.1. Overtime

Several recent reviews indicate that overtime and extended workdays are associated with a higher risk for cardiovascular disease, self-rated health problems, fatigue and shortened sleep (Van der Hulst, 2003).

The review of Van der Hulst (2003) concluded that the most consistent pathways from long workhours to health were related to an inverse association between long workhours and sleep. In general, long workhours and overtime are associated with reduced time for recovery and difficulties to unwind after work (Rissler, 1977). Although there is no direct relationship between the length of the workweek and daily sleep, very short sleep (6 hours or less) is related to longer weekly workhours than midrange (over 6 but less than 9 hours) or long sleep (9 hours or more) in the general population (Kronholm, Härmä, Hublin, Aro, & Partonen, 2006). Excessive weekly workhours (overtime, 50 hours or more) have been shown to be related to shortened sleep (Kageyama, Nishikido, Kobayashi, & Kawagoe, 2001; Åkerstedt et al., 2002), but not to insomnia (Åkerstedt et al., 2002; Härmä, Kivistö, Kalimo, & Sallinen, 2003). The relationship between long workhours and health is also dependent on work demands. In a recent study, overtime was associated with a higher need for recovery solely in employees who experienced high job demands according to the job-strain model (Van der Hulst, Van Veldhoven, & Beckers, 2006).

2.1.2.2. Extended work shifts

Extended work shifts can be defined as shifts taking longer than 8 hours. In shift work, the use of 12-hour shifts especially has become very common. In some countries, on certain working areas, 16-hour shifts and even 24-hour shifts are used. As shown by the three-process model of sleepiness, (Folkard et al., 2005), sleepiness basically grows exponentially by the total time spent awake. However, since the time of the day has simultaneous strong influences on sleepiness, the effect of extended work shifts on sleepiness depends more on the time of the day than the time of the shift. For example, the effects of a 12-hour work shift on sleepiness and the interaction of the long work shifts and sleep deprivation were recently studied by Sallinen et al. (2004). During this experimental study among process operators, objective sleepiness was measured with a continuous electroencephalography/electro-oculography (EEG/EOG) recording and sleep latency tests. Subjective sleepiness was measured with the Karolinska Sleepiness Scale. The results showed that the last hours of a single 12-h dayshift with frequent pauses were not associated with an increase in sleepiness. The majority of the studies comparing 8- and 12-hours shifts refer still to some possible negative consequences of the 12-hour shifts on sleepiness (Smith, Folkard, Tucker, & Macdonald, 1998).

Generally speaking, the literature on the preference of 8- or 12-hour work shifts is controversial (Axelsson, Kecklund, Åkerstedt, & Lowden, 1998; Baker, Heiler, & Ferguson, 2001; Fischer, de Moreno, Notarnicola da Silva Borges, & Louzada, 2000; Lowden et al., 1998; L. Smith et al., 1998; Smith, Wright, Mackey, Milsop, & Yates, 1998; Tucker, Smith, Macdonald, & Folkard, 1999, 2000). The controversial results are mostly related to the differences in shift and work characteristics between the 8- and 12-hours shift systems in addition to the difference in shift length. For example, the direction of rotation, the number of consecutive night shifts and the starting times of the shifts may differ. The literature fails to provide an answer to the question of the possible effects of more than 3-4 consecutive extended work shifts on sleep/wakefulness, since most onshore 12-hours shift systems are based on normal weekly work hours.

2.1.2.3. Extended work periods

In this report, extended work periods are defined as work periods with more than 40 hours a week lasting at least one week and including shifts with a length of over 8 hours. The extended work periods are normally followed by extended periods of compensatory leave to allow for sufficient recovery. Extended work periods are typically made in 12-hour shifts to enable the use of only two shift groups for the specific length of the work period, normally one - three weeks. The use of 12-hour shifts for 7 consecutive days makes 84 hours a week. Extended work periods are useful when there is a need to minimize the coexisting on-site staffing. They are frequently used in offshore oil industry, and are also used in other distant or separated areas like in mining work (Heiler, Pickersgill, & Briggs, 2000) and construction projects (Persson, Orbaek, Kecklund, & Åkerstedt, 2006; Persson et al., 2003).

Onshore work

The NIOSH review of Caruso reviews six field studies examining extended work shifts which had more than 40-hours of work per week. Based on the literature, there are only occasional studies on the effects of extended work periods in onshore work. Fischer (Fischer et al., 2000) studied a change from an 8-hour 3-shift rotation of the shifts with an average of the 41 hours a week to an 12-hour shifts system with 48 hours a week in a petrochemical plant. In the shift system with extended work periods a significant reduction in subjective sleepiness was found during day shifts and at the end of the 12-hour night shifts. However, there was no reduction in sleepiness in the new shifts system during successive night shifts. Novak and Auvil-Novack (1996) studied the effects a 12-hour fixed night and 12-hour day/night rotation shift systems in 45 intensive care unit nurses. Many nurses reported that changing from night work to day activities was fatiguing. According to Tucker (Tucker, Macdonald, Folkard, & Smith, 1998), the comparison of 8- and 12-hour shifts in rapidly rotating shifts systems with 45 h/wk showed fewer symptoms of chronic fatigue in the 12-hour shift systems. Persson et al. (2003) compared the effect of a 12 hour/7 day shift system - requested by the workers - to a 40-hour schedule. The 84-hour group did not show any signs of elevated fatigue or sleepiness compared to the group with normal work hours.

Offshore work

For the evaluation of specific shift systems of offshore work, field studies with objective on-site recording of the outcomes can be regarded as most valid designs, making it possible to directly compare the different shift systems to each other. Questionnaire studies are also valuable to evaluate the general effects on the perceived health. Intervention studies testing different shift systems by the same group of workers would be even more relevant but such studies were not available from offshore work according to our literature search.

Questionnaire studies

According to Parkes (1998) a significantly higher proportion of the offshore workers (54%) than onshore workers (30%) reported sleep problems. In a questionnaire of onshore (n=836) and offshore (n=774) workers, offshore workers in night shifts reported a somewhat longer average sleep duration (about 6.6 hours) than onshore workers (5.7 hours). During day shifts and days off, sleep length did not vary between the groups. Smith et al. (2001)compared the symptoms among seafarers, installation workers and onshore workers. Even thought the response rates of the seafarers and installation workers were low, (21-35 %), the results indicate that seafarers and installations workers have about 10% more complaints of poor sleep (difficulties falling asleep, wake during sleep and restless sleep) than onshore workers. However, the opportunities for rest were similar for the installation and onshore workers, but clearly fewer for seafarers.

Among offshore workers, shift work, individual differences and job type all predict specific health outcomes when evaluated simultaneously by a multivariate analysis (Parkes, 1999). Sleep duration and quality are unfavourably affected by the weekly rotating shift schedules. Lauridsen and co-workers (1991) studied the effect of different 12-hour extended work periods on sleeping difficulties and health among 1730 offshore employees. Sleeping difficulties and the use of sleeping pills generally decreased as the period of the offshore period lengthened. Workers on the rotating weekly shifts and those with the starting time of the 12-h shifts at 00 and 12 (compared to 06 and 18) especially suffered from increased sleeping difficulties, interrupted sleep and waking up too early. Sleeping problems and the use of sleeping pills were especially frequent in the beginning of the night shifts and after the change from night to day or from day to night shits of the swing shift systems.

In the PSA questionnaire of 2005 (Lauridsen, et al., 2006), subjectively reported sleep problems were somewhat different according to the shift system (n= 9945). The number of shift workers that did not "sleep well" (rarely or hardly ever) was higher in the 7N-7D shift system (10.0%,) than in the 7D-7N (7.6%) or in the 14N/14D (7.3%). Not sleeping well during the last few nights before going offshore was higher in the 7D-7N (20.1) than in the 7N-7D (15.8%) or in the 14N/14D (15.6). On the other hand, not sleeping well during the first few nights after an offshore tour was higher in the 14N/14D (28.3%) and 7D-7N (27.7) than in the 7N-7D (14.1%). The percentage of subjects being awake more than 12 hours before the shift was higher in the 7N-7D (34.1) than in the 14N/14D (17.9%) or in the 7D-7N (10.2%).

Field studies

The research group of Josephine Arendt (Barnes, Deacon, Forbes, & Arendt, 1998; Barnes, Forbes, & Arendt, 1998; Gibbs, Hampton, Morgan, & Arendt, 2002) has made three separate studies on the circadian adaptation of offshore oil rig workers working in different rotation systems using urine melatonin as a circadian marker. On the rotation system involving 14 day shifts (06-18) and 14 night shifts (18-06), the workers adjusted to the night shift rhythm 1.3-1.8 h/day by phase delay, showing a good adaptation at the end of the first week (8-10 hours) and almost a permanent circadian phase delay after the 2 weeks of consecutive night shifts (Barnes, Deacon et al., 1998). The three groups were studied both in winter and in summer in the north (61°North). In the second study (Gibbs et al., 2002) on the rotation system involving a swing shift of 7 night shifts (18-06) and then 7 day shifts (06-18), a rather similar average phase delay took place during the first 7 night shifts. However, this study showed larger individual differences than the first study.

In the third study (Barnes, Forbes et al., 1998) on a rotation system involving a swing shift of first 7 day shifts (18-06) and the following 7 night shifts (00-12), no change in adaptation took place during the night week among a group studied in November (61°North). However, almost a full adaptation was found among a group studied in March. Further on, the adaptation in this group in the same shift system and floating drilling rig took place by phase advancement, opposite to the first study (Barnes, Deacon et al., 1998). In November, when no circadian adaptation took place during the night week, sleep length of the group was about one hour shorter during the night week compared to the day week.

Björvatn et al. (1998) studied the adaptation of the subjective sleep-wakefulness rhythm on the rotation system of 14 day shifts (07-19) and 14 night shifts (19-07), separated by three weeks off. In this study, the re-adaptation of the sleep-wakefulness at home after the 14 consecutive night shifts was studied. During the night shifts, the sleepiness ratings showed adaptation within a few days. Re-adaptation to day work after the 14 night shifts was slower, the sleepiness ratings being high about 4-6 days the return journey. Within the night shifts, the sleepiness was clearly highest at the end of the night shifts.

In a study by Bjorvatn et al (2006) which used a randomised, placebo-controlled design, both subjective and objective sleep-wakefulness rhythm was studied on the swing rotation system of 7 consecutive night shifts (06:30 - 18:30) and 7 consecutive day shifts (06:30 - 18:30). Both subjective and objective measures improved gradually during the consecutive night shifts, indicating a full adaptation during the first week. The return to day work after the night shifts led to a clear increase in subjective sleepiness and a weakening of sleep parameters, the re-adaptation of sleep-wakefulness taking about 4-6 days. During the rotation day from night to day shifts, less than 4 hours of sleep was obtained according to the used actigraphs and sleep was shortened to less than 6 hours for many days following the shift back to day work.

In a field study of 260 offshore workers (Parkes, 2002), the effects of the two weekly rotating shift systems (7N+7D and 7D+7N) and the fixed shift patter of 14 nights or days were compared to each other. Although the personnel indicated a widespread preference (87%) for the 7N+7D shift system, this shift system gave rise to the largest sleep deficit (20.3 hours) during the 2 week journey and day-shift levels of subjective sleep and alertness were not experienced during the whole offshore work period. The 7D+7N shift system also produced impaired sleep and alertness during the week with the night shifts and was strongly disliked by the workers. 14D/14N shift system produced the lowest overall sleep deficit for both day and night shifts (12-16 hours). The shift system produced little or no significant deterioration in alertness over the course of the shifts.

Parkes and Clark (1997b) have also compared the fixed 2-week and 3-week continuous night/day rotations to each other by visual analogue scale diaries in a sample of 55 subjects. The results showed no significant differences in alertness between the two shift systems, but subjective alertness showed a declining trend during the third week offshore compared to the second week.

In conclusion, long work shifts and excessive overtime seem to be related to shortened sleep but not to insomnia. The relationship between long overtime and fatigue is dependent on work demands and possibilities for recovery. Surprisingly, most onshore studies examining extended work periods having both extended work shifts and more than 40-hours of work per week do not show increased fatigue compared to shift systems with shorter average work hours. There is some evidence that offshore workers have more sleeping problems than onshore workers. In offshore work, sleep duration and quality are unfavourably affected by the weekly rotating shift schedules, the permanent two-week day/night shift rotation being superior to the other shift systems in relation to circadian adaptation and sleep/wakefulness at work.

2.2 Performance and operational risk

An operational risk caused by an error in work performance is determined by the potential consequences and likelihood of the error. In some tasks, the serious aftermaths of a human error are largely prevented by for example technology-based safety measures (e.g., the automatic train control system) whereas in tasks without such measures, a corresponding error may pose a great operational risk. In the latter case, in particular, attempts to optimise human performance can be considered as a high priority action. These attempts are naturally based on the knowledge of the main determinants of performance in a particular job.

2.2.1 Shift work

Performance at work is influenced by several factors including for example competence, motivation and external conditions (e.g., noise, lighting). In shift work, performance also varies greatly according to the time of the day, time since awakening and the quality and quantity of the latest sleep period.

Experimental sleep deprivation studies

The role of the time elapsed since the last sleep period is well illustrated by the study of Dawson and Reid (1997). The authors showed that 21 h of continuous wakefulness starting at 7 a.m. produced impairment in eye-hand coordination test equivalent to near 1 per mil blood alcohol concentration. In a later study, it was found that other sorts of cognitive performance, too, such as performance on a traditional vigilance task or on a dual task, fitted quite well to this rule of thumb (Williamson & Feyer, 2000).

Experimental laboratory studies examining the effect of the amount of prior sleep on performance are numerous. Recently, the emphasis of these studies has been on the effects of partial sleep debt accumulating over several consecutive days. For instance, a study by Van Dongen et al (2003) demonstrated that 6 h of sleep per night for about two weeks impairs vigilance performance as much as 24 h of total sleep loss. If sleep was obtained only during 4 h per night the same effect was seen in no less than a week. In another similar study, it was found that recovery of vigilance performance from a week with mild to moderate sleep restriction (5 or 7 h of sleep per day) remained incomplete even after 3 days of recovery sleep (Belenky et al., 2003). This finding suggests that the brain, since having once adapted itself to a certain level of performance in response to cumulative sleep debt, does not rapidly return to baseline.

The experimental sleep debt studies have also revealed that it is not only vigilance that is deteriorated by sleep debt, but also higher-order cognitive functions called the executive functions are vulnerable to sleep restriction (Jones & Harrison, 2001). These functions are needed for example when a task requires us to inhibit our over-learnt responses or to perform more than one task simultaneously.

In regard to the operational risk, risk taking behaviour and an ability to monitor one's own performance are among the most important higher-order cognitive functions. There are both laboratory and questionnaire studies suggesting that sleep loss and sleepiness are associated with a decreased threshold for taking a risk in a variety of cognitive tasks (Killgore, Balkin, & Wesensten, 2006; O'Brien & Mindell, 2005; Roehrs, Greenwald, & Roth, 2004). As to the ability to self-monitor performance under sleep deprivation, results are ambiguous. While studies of acute sleep deprivation suggest that this ability remains quite intact, a study into a week of simulated night shifts showed that it was clearly impaired, being only moderate in accuracy (Baranski & Pigeau, 1997; Baranski, Pigeau, & Angus, 1994; Lamond et al., 2003).

From a practical viewpoint, it is also worth noticing that cognitive deficits from sleep debt show large and stable inter-individual variation (Van Dongen, Baynard, Maislin, & Dinges, 2004). In addition, it seems that this trait-like vulnerability to sleep debt varies greatly even in a very selective population of shift workers and does not match with self-evaluated increase in sleepiness (Van Dongen, 2006). In other words, a certain proportion of shift workers are very vulnerable to sleep debt, but they are not aware of their vulnerability, as they do not experience an exceptional sleepiness as compared to their less vulnerable co-workers.

In all, these findings suggest that a person is more inclined to make errors in various mental tasks under sleep debt than after normal sleep. In addition, these errors are not only due to nodding offs or actual falling asleep, but also to impaired executive functioning. However, inter-individual differences in a performance-based response to sleep debt are great, even though subjects' own experiences of sleepiness may not differ in a similar manner.

Shift work studies

Studies of the cognitive effects of a long-term exposure to shift work are scarce. To our knowledge, there is only one study of this sort, showing impaired cognitive functioning among shift workers compared to workers never exposed to shift work (Rouch, Wild, Ansiau, & Marquie, 2005). It is likely that impaired cognitive functioning is due to repetitive circadian disruptions and chronic sleep deprivation, which are inevitable consequences of shift work. Interestingly, the study of Rouch et al. also showed that the cognitive impairment was not clearly observed in participants who had stopped shift work a few years prior to the study, suggesting a possible reversibility of the effects.

The short-term cognitive effects of various shifts have been examined in a number of field and laboratory studies, usually employing quite simple tests. A common finding has been that psychomotor, vigilance and routine-like cognitive functioning is at its worst in the night shift, especially during the early morning hours (Åkerstedt, 2007). At this point, both the circadian phase and the time since awakening push performance into its below-average level.

The effects of various shifts on real work performance are a less extensively studied topic in spite of the fact that the question possesses a high practical value. There are some old studies showing that performance on highly attention-dependent tasks (e.g., gas meter reading) is at its worst during the night shift (Bjerner, Holm, & Swensson, 1955; Browne, 1949). In more recent studies, one of the target groups has been train drivers. A classic study by Torsvall and Åkerstedt demonstrated that the incidences of sleepiness verified with electroencephalography recordings were markedly more frequent in night-time than in day-time driving (Torsvall & Åkerstedt, 1987). In addition, four of the 16 drivers had frequent attacks of micro-sleep, which, in some cases, were coincided by omissions of critical signals. The most recent laboratory study also supports the view that train driving is deteriorated when fatigued. The simulated train driving study of Dorrian et al. showed that drivers' failures to act (errors of omission) as well as reduced overall interaction with the train were typical of high fatigue levels equivalent to that observed at the end of a night shift (Dorrian, Roach, Fletcher, & Dawson, 2007). The field study of the same research group showed that train driving when fatigued was associated with increased fuel consumption, heavy breaking and speeding violations (Dorrian et al., 2007).

In addition to train driving, car driving has been studied in relation to time of day and time since awakening. The results seem quite consistent: driving performance at night and after a prolonged period of wakefulness is associated with an impaired performance, probably due to increased sleepiness (Åkerstedt, Peters, Anund, & Kecklund, 2005; Gillberg, Kecklund, & Åkerstedt, 1996).

An exception from the above-mentioned studies on real work performance in shift work is the study of Gillberg et al. (2003). They looked into the performance of process operators in a very realistic thermal power plant simulator and found that the participants performed even better during the night shift than during the day shift, even if the level of sleepiness was higher for the night shift. Possible explanations for this unexpected result are that i) the level of power production was lower during the night shift, ii) the industrial process was not sensitive to minor attentional mistakes due to sleepiness, and iii) the participants were not severely sleepy even in the night shift, probably due to the interesting assignment and coffee consumption.

To sum up, it seems that a long-term exposure to shift work may be accompanied by a reversible impairment of cognitive functioning. Perhaps even more importantly, both laboratory and field studies suggest that night work is associated with marked short-term deficits in both test and work performance measures. However, it is possible that certain characteristics of a task (e.g., attractiveness and difficulty) and a possibility to consume stimulating drinks during the shift may make night-time performance even comparable with day-time performance.

2.2.2 Long work hours

Long work hours can affect cognitive performance by shortening sleep between consecutive shifts and building up high workload within a shift. The cognitive effects of long work hours are largely dependent on the way the work hours are arranged. Do they for example mean long individual shifts but normal weekly work hours (compressed work hours) or high annual work hours?

2.2.2.1 Overtime work

Few studies have looked at the relationship of overtime work with cognitive performance. The most cited study by Proctor et al. examined automotive workers and found that overtime work was associated with impairments in a variety of cognitive functions (Proctor, White, Robins, Echeverria, & Rocskay, 1996). More specifically, those who had worked more than 8 h a day or more than 5 consecutive days during the week preceding the cognitive testing showed impaired performance in several tests of attention and executive functions (the ability to prioritize and plan tasks). This result remained even after controlling for a number of intervening factors such as age, gender and alcohol intake. On the basis of some other studies, it can be assumed that the observed cognitive impairments were at least partly due to shortened sleep and increased fatigue (Dahlgren, Kecklund, & Åkerstedt, 2006).

2.2.2.2 Extended work shifts

Many of the studies examining the relationship of extended work shifts with cognitive performance have compared 12 h and 8 h shift systems with each other. The results from these studies are somewhat mixed. For example three field studies looking into a change from an 8 h shift system to a 12 h system showed no difference in reaction time, vigilance or memory search tests in process operators or in maintenance workers (Axelsson et al., 1998; Lowden et al., 1998; Macdonald & Bendak, 2000; Smith, Totterdell, & Folkard, 1995), whereas one laboratory and two field studies found 8 h shifts better than 12 h shifts in terms of cognitive performance (Rosa, 1991; Rosa et al., 1989; Rosa et al., 1985). An additional finding of interest was that the performance impairment was still present 3.5 years after the introduction of the 12 h system, suggesting that no marked adaptation took place over the long period of time (Rosa, 1991).

The results of our laboratory study are in line with those studies showing no cognitive consequences from extended shifts (Sallinen et al., 2004). Our study focused on 12 h dayshifts that varied in terms of the length of prior sleep (8 or 4 h) and the stability of a simulated distillation process (low or high). We found no impairments in work performance for the last four hours of the shift in any of the four conditions. It must, however, be emphasised that the effective work time during the shift was only 7,5 h and that the shift was always the first in a row. These factors may at least partly explain our finding of surprisingly high quality performance during the final four hours the shift.

A laboratory study by Reid and Dawson (2001) focused on the influence of age. The results demonstrated that the performance of older participants (35-55 y) on short, eye-hand coordination demanding tracking tests declined during a night shift and improved during a dayshift, whereas younger participants (18-30 y) performed evenly in both shift types. This finding implies that long shifts are associated with an increased operational risk especially if they are applied to ageing workers at night work. However, a wider spectrum of cognitive tests and field studies, in particular, are needed to draw reliable conclusions.

An explanation for the above-mentioned contradictory findings of performance during the 12 h shift may lie in the role of workload. The study of Macdonald and Bendak (2000) in production operators, laboratory technicians and maintenance technicians showed that the combination of high workload and 12 h workdays decreased hand steadiness and increased errors in grammatical reasoning more than either of the factors alone as compared 8 h workdays with low workload.

In all, the above-mentioned results suggest that the significance of the length of a shift for the operational risk must be assessed in relation to the overall ergonomics of a shift system and the content of work, and possibly also by taking into account the age distribution of the workers.

2.2.2.3 Extended work periods

Four studies on cognitive performance in extended work periods were identified. One of them was carried out in a laboratory setting consisting of conditions of seven consecutive night shifts and from mild to moderate alcohol intoxication (Lamond et al., 2004). The main finding was that performance was most impaired at the end of the first night shift when the impairment was greater than that observed at a BAC of 1 per mil. For the next two shifts, the performance deficit was equivalent to a BAC of 0.5-1 per mil, and for the remaining four shifts less than seen at a BAC of 0.5 per mil. Overall, these findings suggest that a significant adaptation of performance occurs during a week of consecutive night shifts.

In the field study of Persson et al. (2003), a group of construction workers with a long weekly work time (84 h) was compared to their co-workers with a normal weekly work time (40 h). Somewhat surprisingly, the performance of the long working group showed no deterioration in any of the tests of psychomotor performance, response inhibition and selective attention. The authors concluded that the performance effects of an extended work schedule do not necessarily deviate from those observed with a 40 h workweek in the short-term.

Parkes examined performance changes in 13-18 operators during their two week offshore period consisting of 7 consecutive night shifts and day shifts. The most important finding was that reaction time performance was at its worst during the shift-change phase. In regard to performance on a logical reasoning and a search-and memory task, the results were more complicated and also a learning effect made it difficult to interpret them.

In a later study by Parkes and her co-workers, reaction time performance was tested in various shift systems of offshore personnel (Parkes, Clark, & Payne-Cook, 1997). The shift systems for a 14 day work period consisted of a fixed system (14 consecutive day shifts / night shifts) and two rotating systems (7 consecutive day shifts followed by 7 consecutive night shifts or vice versa). The results showed that level of performance varied least in the fixed shift system, whereas in the 7 nights + 7 days system performance was deteriorated by two 12 h circadian changes; the beginning of the night shifts and the changeover from the night shifts to day shifts. For the 7 days + 7 nights system, the critical phase was the shift changeover that made the system inferior to the 14 day period of the fixed system. During the 14 consecutive night shifts, performance showed some improvement towards the end of the period.

As a whole, the results of extended shift periods suggest that significant adaptation occurs over a period of several consecutive night shifts and that a rather long weekly work time does not necessarily lead to impaired performance. However, the studies behind these conclusions have been conducted either in laboratory conditions or in workers without normal domestic activities due to a long distance between their workplaces and homes. These features of the studies clearly restrict the generalisation of the results to a more typical condition of living at home during workweeks.

2.3. Accidents and injuries

2.3.1. Shift work

In their review of five studies, Folkard and Tucker (2003) concluded that injury risk increased 18% in the afternoon shift and 30% in the night shift compared to the morning shift. However, most of the authors of the original papers did not report precise details of the shift system in use, but companies studied by Levin et al. (1985) and Smith et al. (1994) used the rotating three-shift system. In addition, based on seven studies, Folkard and Tucker calculated that injury risk was 6% higher on the second night, 17% higher on the third night, and 30% higher on the fourth night. On the other hand, five out of these seven studies showed that injury risk was 2% higher on the second morning shift, 7% on the third morning shift, and 17% higher on the fourth morning shift. Based on 10 studies, Folkard and Åkerstedt (2004) had calculated that during the night shift the injury risk rose 20% from the first to second hour, but then fell about 50% reaching the minimum at the end of the shift. However, there is a slight increase in injury risk between 03:00 and 04:00.

Based on the review of 19 studies, Costa (1996) concluded that eight studies showed the highest injury risk during night shift, one during day shift, two during morning shift and two during afternoon shift. In three studies there was no difference between day and night shifts. The peak hours for injuries were around 10-11 am and 15-16 hours pm. During the morning shift more injuries took place during earlier starting hours.

The National Longitudinal Survey of Youth (NLSY) cohort is comprised of 12 686 men and women who were from 14 to 22 years of age when first surveyed in 1979. Follow-up surveys were made annually, but after 1996 biannually. Based on the data set with 110 236 job records, Dembe and his co-workers (2006) found that workers in the evening shift had a 43% elevated risk of accident compared to the day shift. In night shift the risk was 30% higher. Rotating shift increased the risk by 36% and irregular shift by 15%.

In an American paint company, the injury rate of workers in rotating shifts was only 5.5% of the average in U.S. paint industry. However, during night shifts the injury rate was slightly higher than during day and evening shifts. During the eighth working hour in particular the night-shift workers had a 78% greater injury rate than the day-shift workers. On the other hand, during the first working hour in the day shifts the injury rate was 69% higher than in the night shifts (Levin, Oler, & Whiteside, 1985).

In a German metallurgic plant they used continuous work-week with shift rotation after four days. There were significantly more accidents during night shift than during morning and afternoon shifts. In the morning shift the peak of accidents was found on the second day. In the night shift the peak was noticed on the third day. In the morning shift the highest number of accidents was found at the 5th and the 6th hour, in the afternoon shift at the 4th and at the 6th hour, and in the night shift at the 2nd and at the 4th hour (Quaas & Tunsch, 1972).

In 11 textile departments in India they used monthly rotating morning and evening shifts and permanent night shift. Most of the injuries during morning and evening shifts happened during the fourth work hour. The fifth and sixth work hours were the most dangerous during night shift (Nag & Patel, 1998).

In a steel production plant in Singapore, there were significantly fewer injuries during the night shift than during the morning and evening shifts. Mid-morning between 9-10 and mid-afternoon between 14-15 hours were the injury peaks. Injuries during night shift were more severe than those during morning and evening shifts (Ong et al., 1987).

In three fire brigades operating in a North-eastern state in USA, there were more injuries during a 10-hour shift than during a 14-hour shift. The ratio of injuries per alarm was higher during night shift than during day shift. However, the top hours for injuries were the meal times (Glazner, 1996).

In a glass factory and a steel plant operating in Ontario, Canada, highest number of traumatic accidents occurred just before lunch time, at noon. The lowest number of accidents was recorded at night. The peak hours during night shift were between 2 and 4 a.m. (Wojtczak-Jaroszowa & Jarosz, 1987).

In a British engineering company a rotating three shift system was used. Workers in the night shift had 23% more often injuries than in the morning shift. The injuries were also more severe in the night shift among self-paced workers but not among machine-paced workers (RR = 1.82) (Smith, Folkard, & Poole, 1994).

In six large automotive plants in Ontario, Canada, a rotating shift work with three shifts was used. The severity index of injuries was lower for afternoon and night shifts than for morning shifts. Injury potential was higher over workers between 30 to 45 years of age (Barsky & Dutta, 1992).

The British Workplace Employee Relations Survey from 1998 is a nationally representative sample of workplaces in Britain with 10 or more workers. The length of the working week was negative but significantly correlated with injury rates so that the longer work week the employees worked, the lower the injury rate was. On the other hand, shift work was positively and significantly associated with injury rate (Robinson & Smallman, 2006).

A survey among 22,000 New Zealand Blood Donors showed that working rotating shifts with night shifts double the risk of occupational injury. Without night shifts the risk was slightly lower (RR =

1.8). Working three or more nights in a week also increased the injury risk two times higher. On the other hand, working more than 40 hours a week was a risk factor for occupational injury (Fransen et al, 2006).

The analysis of fatal occupational injuries in Australia, 1982-1984, showed that during night shift the number of fatalities is double compared to the number of workers in that shift. Most fatalities occurred from late morning to early afternoon and the fewest between 23 and 01 at night with a further drop at 04. The risk for human error was the greatest during the early morning hours between 00 and 06 (Williamson & Feyer, 1995).

In conclusion, the night shift seems to have a 30% - 100% higher accident rate than the day shift. The risk increases with the number of consecutive nights. There is a slight increase of injuries around 03 in the early morning. On the other hand, starting very early the morning shift increased the risk of injury. However, the peak hours for injuries during the morning shift were around 10 and 15. During the evening shift there was an elevated risk of injury. Rotating shift work also increased the risk of occupational injury. Please, notice that not every study reported the shift system used. In most studies, however, rotating shift system was used.

2.3.2. Long work hours

2.3.2.1. Extended work days

In their review Duchon and Smith (1993) found seven studies on the relationship between a 10- or 12-hour workday and occupational injuries. Six studies showed that extended workdays increased the accident risk. Only in one study a decrease of injury rate was found during the last three hours of the shift.

Folkard, Lombardi and Tucker (2005) concluded in their review of four studies that variations in shift length from 4 to 9 hours had little impact on injury risk. But a 10-hour shift increased the injury risk by 13%, and a 12-hour shift by 28% (Folkard & Lombardi, 2006). In the twelfth hour the injury risk was more than double compared to that of the first 8 hours (Folkard & Tucker, 2003).

In a review of 52 studies, Caruso et al. (2004) found two studies on overtime and accidents. Both of them showed that overtime (working 12 hours per day) increased the risk of injury.

Based on the NLSY data set, Dembe and his co-workers (2005) found that people working over 60 hours per week had a 23% higher accident rate than those working normal week hours. Working over 12 hours daily increased the accident risk by 37%. Working in jobs with overtime schedules was associated with a 61% higher accident risk compared to jobs without overtime.

By the same NLSY data set with 500 American construction workers, Dong (2005) showed that the injury rate increased steadily along with hours of overtime. Those working over 8 hours per day had 1.57 times more injuries than those who worked 8 hours a day at the most. When workers worked over 50 hours a week, their injury risk was almost double (OR = 1.98).

In the analysis of more than 1.2 million occupational accidents within a German working population Hänecke and her co-workers (1998) showed that the accident risk increased exponentially after the 9th hour at work. After 12 hours of work the accident risk was double compared to the 8th hour. In the evening and night shifts the accident risk during the 8th work hour was higher than in the morning shift.

A change from an 8-hour to a 12-hour shift was carried out in a large Canadian manufacturing company. Ten years after the change all accident rates were reduced on the 12-hour shift schedule. However, this was not found among female workers. On the other hand, off-the-job injuries increased after the change to a 12-hour shift (Laundry & Lees, 1991).

In a large American manufacturing company a group of production workers changed from an 8-hour shift to a 12-hour rotating shift. No significant change in the occupational accident rate was noticed. The researchers did not analyse the effect of extra hours on the accident rate. In the questionnaire study, overwhelming majority of the workers prefer the change because of better sleep, and health, as well as a better family and social life (Johnson & Sharit, 2001).

In a nuclear power plant in the United States, operators in a 12-hour shift made more operator-errors than those in an 8-hour shift. Operations overtime was positively associated with the frequency of violations and safety system failures. Overtime worked by the technical staff also increased the number of safety system failures. However, the number of operator-errors was not significantly related to operations overtime and overtime worked by the maintenance staff not to safety performance indicators (Baker, Olson, & Morisseau, 1994).

The workers of an Australian electric power station reacted positively to the change from a 8-hour shift to a 12-hour shift. The number of accidents was too small to draw any conclusions. However, the error rate increased at the end of a 12-hour shift (Mitchell & Williamson, 2000).

In an Australian coal mine, they used three shift systems during 33 months. First, they had the traditional backward rotating 8-hour/7-day shift, then a 12-hour/7-day shift, and finally, a 12-hour/5-day shift. The only significant change was from the first to the second shift system in the coal preparation plant, where injuries decreased by half of the original level (Baker, Heiler, & Ferguson, 2003).

We can conclude that an extended workday seems to increase the risk of occupational accident. If the length of a workday was 10 hours, the accident risk increased by 13% compared to an 8-hour workday. If the workday took 12 hours, the risk increased from 28% to 100%. On the other hand, the shift from an 8-hour to a 12-hour workday has inconclusive effects on accidents: In one of the studies the accident rate was reduced, in the other no change could be found. However, the two studies showed an increase of operator errors during the very long workday. Working with overtime schedules increased the accident risk by 61%. Working over 50 hours per week double the accident risk, but working over 60 hours increased the risk only by 23%. However, the earlier study was done by construction workers with a high accident risk, whereas the latter study concerned the general working population.

2.3.2.2. Extended work periods

Occupational injuries are a considerable problem at offshore oil drilling rigs. Based on the data-base "Injuries in Offshore Drilling" Lauridsen and Tönnesen (1990) found 3200 injuries in the Norwegian offshore drilling industry in the time period from 1980 to 1987. There was no difference between day and night shift on injury rate, although the number of injuries was higher during day shifts than during night shifts. On the other hand, the drill crew were injured more often between 00-06 than between 18-24 hours. During a 12-hour work period the lowest injury rate was found between 5.5 and 7.5 hours and during the last half hour of the shift. More injuries happened during the first day during the work period. The injury rate was higher for those remaining at work during the breaks.

In the British offshore installations the personnel worked two weeks and then had two weeks off. Forbes (1997 cited by Parkes and Swash, 2000) showed that the accidents of these workers decreased in the second week. The peak of accidents was found on the first day after a shift change. Those working fixed shifts have an increased accident risk on the 5th and the 6th day. On the other hand, the injury rate among drillers increased in the first hour, but then decreased during the successive 12 hours of the shift.

Based on three large databases of Health and Safety Executive and two multi-national oil and gas companies, Parkes and Swash (2000) showed that there was an increased risk of serious injuries and fatalities relative to less serious 3 or more day absence injuries with increasing days into installations. This ratio increased even more when the stay on the installation was exceeded by two weeks. However, the results are based on the absolute injury rates because of absence of exposure data. On the other hand, there was strong evidence that injury severity was greater during the night shift than the day shift. When the length of shift exceeded 12 hours, disproportionately more severe injuries occurred. The peak hours for serious injuries were between 06-08 and 00-02.

Smith, Lane and Bloor (2001) found in their survey of 11 314 workers of a multinational oil company that the majority of injuries occurred between 09-16 hours. The injury frequency was significantly higher in the first four hours of the shift. On the other hand, injuries did not increase after lunch or between 02-02 at night. Injury frequency was the greatest during the first tour week and declined steadily over the course of a tour.

There were 518 medical examinations of injuries and poisonings on an American oil rig operating in the Mediterranean Sea during one year. Oil drillers and deck hands were most often involved in injuries. The number of injuries was three times higher during winter than during summer. The top hours for injuries were early in the morning and after the main meal. Direct stroke and jamming were the main causes of injuries (Valentic et al, 2005).

In conclusion, the first day and the first hour of the shift was the most dangerous time of the shift. The accidents on the installations decreased during the second week on duty. On the other hand, if *the shift exceeded two weeks, the risk of accidents increased and they were more serious. Also, if the length of the shift exceeded 12 hours, the risk of severe accidents increased.*

Maintenance work

Most of serious occupational injuries on oil rigs during night shifts happened in the maintenance work (Lauridsen, et al., 2006). Relationships between maintenance work and accidents have been examined in two studies. In two Finnish chemical plants, it was shown that maintenance staff had a 1.5 times higher accident frequency than operations personnel (Väyrynen, Pekkarinen, & Tornberg, 1994). Ray et al. (2000) showed with 25 manufacturing plants in Alabama, USA, that the higher maintenance audit score, the lower the accident frequency.

In conclusion we can say that maintenance work is more hazardous work than normal production work. Perhaps working in unexpected situations makes maintenance so dangerous.

2.4. Health

2.4.1 Shift work

Findings from prospective and cross-sectional studies indicate that shift work is associated with an elevated risk for coronary heart disease (CHD) and mortality (Fujino et al., 2006; Kawachi et al., 1995; Knutsson, Hammar, & Karlsson, 2004; Tenkanen, Sjöblom, Kalimo, Alikoski, & Härmä, 1997). The risk level depends on the socio economic status (Boggild, Suadicani, Hein, & Gyntelberg, 1999). Shift work has predicted an increased risk of hospitalization due to circulation diseases (Tuchsen, Hannerz, & Burr, 2006) in a population-based cohort of men and women. Moreover, the risk for coronary heart disease has been shown to increase with the number of years of shift work in nurses (Kawachi et al., 1995) and among paper industry workers (Karlsson, Alfredsson, Knutsson, Andersson, & Toren, 2005; Knutsson, Åkerstedt, Jonsson, & Orth-Gomer, 1986).

The nature of causal link between shift work and heart disease in not well established. However, studies exploring possible biological underlying mechanisms have been recently intensified. In this respect it has been found that shift work predicts the onset of hypertension in male workers (Sakata et al., 2003) as well as the progression of mild hypertension into severe hypertension in a sample of 64954 male workers (Oishi et al., 2005). The evidence linking shift work to the development of blood pressure is not entirely consistent, and for example Murata et al (1999) did not find an association between shift work and blood pressure in their follow-up study of 177 shift working men and 63 controls.

Studies investigating the effect of shift work on the incidence of diabetes mellitus compared with the onset in day-shift work have revealed that shift work is an independent risk factor for the onset of diabetes mellitus (Morikawa et al., 2005; Sakata et al., 2003; Suwazono et al., 2006). Shift work has also been cross-sectionally associated with elevated levels of metabolic syndrome risk factors (high concentrations of triglycerides, low HDL-cholesterol concentration and high BMI (excluding men in the 60- year-old group) (Karlsson, Knutsson, & Lindahl, 2001) and elevated levels of homocystein, a risk factor for cardiovascular disorders, among long-haul bus drivers (Martins, D'Almeida, Vergani, Perez, & Tufik, 2003). Nakamura and colleagues (1997) reported a higher level of total cholesterol and higher abdominal to hip ratio in shift workers compared to day working counterparts. Cross-sectional data of 665 day workers and 659 three-shift workers in two plants showed that a higher proportion of shift workers than day workers had high triglyceride levels (> or =1.7 mmol/l), low levels of HDL-cholesterol (<0.9 mmol/l) and abdominal obesity (waist/hip ratio>0.9). The risk of low HDL-cholesterol was doubled in shift workers, while the prevalence of hyperglycaemia (serum glucose > or =7.0 mmol/l) was similar in day and shift workers. Controversial results have also been reported. In a 1-year follow-up, BMI and LDL/HDL changed in a favourable direction after starting to work in shifts, and a change in smoking habits was the only unfavourable change observed in the cardiovascular risk factors measured (van Amelsvoort, Schouten, & Kok, 1999).

Shift work is associated with increased gastric and duodenal ulcers (Pietroiusti et al., 2006; Tuchsen, Jeppesen, & Bach, 1994), other gastrointestinal disorders (Costa, 1996), and also with a higher prevalence of common infections (common cold, flu-like illness, and gastroenteritis) (Mohren et al., 2002).

Results on the relationship between shift work and psychological health are equivocal. Starting to work in shifts has been suggested to induce acute changes in perceived criticism from others, sense of purpose and control, and psychosomatic complaints (Healy, Minors, & Waterhouse, 1993). In a cross-sectional study of 153 employees, shift workers and day workers had similar levels of depressive symptoms (Goodrich & Weaver, 1998). In another study of nearly 500 nurses shift work was unrelated to self-rated physical health or depression (Skipper, Jung, & Coffey, 1990). In contrast the study by Scott, Monk, and Brink (1997) with 98 participants suggested that shift work may predict an increased life-time incidence of depression. At present, it is not clear whether shift work influences psychological health of the workers in the long run. Additional evidence from high quality follow-up studies with a good control over confounding factors is needed. Shift workers are often a self-selected group and have generally a good health. Therefore the possible detrimental effects of shift work on mental and physiological health may not be captured when shift workers and non-shift workers are compared. Data on life-time exposure to irregular working hours and studies following those who have moved to day shifts may provide additional important information on the long term health effects of shift work.

Exposure to light-at-night, including disturbances of the circadian rhythm, possibly mediated via the clock genes and melatonin synthesis has been suggested as a causal factor for breast cancer. A body of evidence links shift work with breast cancer incidence (Davis & Mirick, 2006; Megdal, Kroenke, Laden, Pukkala, & Schernhammer, 2005; Schernhammer, Kroenke, Laden, & Hankinson, 2006). There is evidence suggesting that shift work may increase the risk of colonrectal cancer in women (Schernhammer et al., 2003) and the risk of prostate cancer in men (Kubo et al., 2006). In a meta-analysis by Mozurkewich et al (2000) shift work was found to be a significant predictor of the risk of preterm birth (OR = 1.24). Shift work during pregnancy can increase the risk of delivering a small-for-gestational-age infant (Croteau, Marcoux, & Brisson, 2006; Zhu, Hjollund, & Olsen, 2004).

Life-style factors such as smoking and obesity appear to be especially relevant for the health of shift workers. A study by Tenkanen et al (1998) showed that the effects of shift work and life-style factors on the risk of CHD may be additive in shift workers, whereas a similar joint effect of shift work and life-style factors was not observed in day workers. Exposure to shift work gives rise to increases in BMI, over and above the normative effects of ageing on BMI shown by day-shift workers (Parkes, 1999). These results suggest a relationship between years worked in shifts with BMI and waist-to-hip-ratio (WHR) in both males and females. Whether this might reflect an effect of changed dietary habits or a metabolic effect is not yet clear.

In nurses shift work has been related to increased low-back musculoskeletal disorders (Lipscomb, Trinkoff, Geiger-Brown, & Brady, 2002). In a study by Trinkoff et al (2006), however, shift work was unrelated to musculoskeletal disorders; only a combination of long work days and a short time off between the shifts was associated with a higher incidence of musculoskeletal disorders.

Circadian stress is not the sole environmental factor explaining the health hazards associated with working in shifts. There is evidence suggesting that shift work increases experienced job-related stress and associates with a lower job control in shift workers compared to day workers (Harada et al., 2005). From other studies we know that job stress and job satisfaction are also important predictors of mental and physiological health (Faragher, Cass, & Cooper, 2005; Kivimäki et al., 2006).

Noise may also have interactive effects with shift work on psychophysiological activity (Boucsein & Ottmann, 1996) and cardiac health (Virkkunen, Härmä, Kauppinen, & Tenkanen, 2006). This may be particularly relevant to offshore conditions in which hearing loss is also considered to be a significant health challenge (Morken, Bratveit, & Moen, 2005, from the abstract). Health habits may have different effects on cardiac health, too, depending on whether a person is working in shifts or not (Tenkanen et al., 1998). A combination of both mental and physical demands at work has been suggested to result in unfavourable effects on cortisol and adrenaline reactivity or recovery, compared with workers doing mainly mental or mainly physical work (Sluiter, Frings-Dresen, van der Beek, Meijman, & Heisterkamp, 2000).

To sum up, shit-work is associated with an elevated risk of several diseases including coronary heart disease and its risk factors, gastrointestinal disorders, breast cancer, and possibly with some other cancers as well. Shift work also appears to have adverse effects on reproductive function. Circadian stress is the major influencing factor in these associations; factors such as socio economic status, job type, psychosocial stress, health habits, off-work stressors and shift work are in many cases likely to be included.

2.4.2 Long work hours

2.4.2.1. Overtime

Studies on the associations between overtime and health have focused mostly on men and there appear to be some inconsistencies in the results of these associations. Several papers have reported an association between overtime and CHD, acute myocardial infarction, blood pressure (Hayashi, Kobayashi, Yamaoka, & Yano, 1996; Iwasaki, Sasaki, Oka, & Hisanaga, 1998; Liu & Tanaka, 2002; Nakanishi, Yoshida et al., 2001; Park, Kim, Cho et al., 2001) and CHD risk factors such as BMI (Nakanishi, Nakamura, Ichikawa, Suzuki, & Tatara, 1999) and unhealthy weight gain (Nakamura et al., 1998). Long working hours (mean of previous month ≥ 11) have been shown to predict acute myocardial infarction in men (Sokejima & Kagamimori, 1998). However, working long hours (≥10 hour) predicted negatively the development of hypertension in a 3-year follow-up of initially hypertension free male office workers (Nakanishi et al., 1999). The results were not controlled for socioeconomic differences.

The incidence of the metabolic syndrome was higher among those who worked over 50 hours over /month (Kawakami, Araki, Takatsuka, Shimizu, & Ishibashi, 1999), whereas a study by Nakanishi et al. (Nakanishi, Nishina et al., 2001) concluded the opposite. They reported overtime to be a negative risk factor for the development of diabetes mellitus in Japanese male office workers. Both studies had only baseline working-hour data at their disposal which makes the interpretation of a longitudinal effect difficult. The influence of long work hours on reproductive outcomes is a cause for concern. A meta-analysis reported a possible weak relationship between overtime and preterm births, and another study reported an association between long work hours and subfecundity (Mozurkewich, Luke, Avni, & Wolf, 2000; Tuntiseranee, Olsen, Geater, & Kor-anantakul, 1998).

Fatigue has also been found to increase with the number of hours worked in aweek in a sample of 238 men (Park, Kim, Chung, & Hisanaga, 2001) and in another sample of 72 men (Iwasaki et al., 1998). Working long hours may also increase the odds of subsequently experiencing depression (Shields, 1999). In the same study by Shields and colleagues moving from standard to long hours was related to unhealthy weight gain in men, with an increase in smoking in both men and women, and with an increase in drinking in women, while no associations were detected for physical activity in their study. In a sample of 3917 nurses Trikoff and colleagues (1998) found that combinations of shift and shift length interacted in association with substance use, so that nurses working night shifts > 8 hr had the highest likelihood of alcohol use and smoking and those working rotating shifts > 8 hr were more likely to report alcohol use. Park (Park, Kim, Chung et al., 2001) reported no differences in health behaviours in the working hour groups. The results for the associations of long working hours and physical activity are mixed (Kageyama et al., 1998; Mizoue, Reijula, & Andersson, 2001; Shields, 1999). Overtime is related to socioeconomic status. One explanation for the mixed findings may be the differences in social economic status differences of the study samples. Studies utilizing within-participant assessments may be considered as the most reliable findings at present.

There is reasonable evidence, although not conclusive in all cases, indicating that long working hours have detrimental effects on health. The most coherent evidence is for CHD; the associations of long working hours and risk factors for CHD also support this view relatively congruently. Overtime has been associated in some cases with poor health habits and increases in body mass. Again, the mixed findings may be due to differences in the socio economic variables and other group differences.

2.4.3.2. Extended work periods

Studies comparing 8- and 12-hour rotas have generally concluded that 12-hour shifts may not necessarily involve risks for the health of employees. At the same time it has to be kept in mind that there are few studies on the possible longitudinal effects of 12-hour shifts on health outcomes.

In nurses, back musculoskeletal disorders have been found to be more common in subjects working 12 or more hours per shift compared to those working an 8-hour shift (Lipscomb et al., 2002). A study by Prunier-Poulmaire, Gadbois, and Volkoff (1998) reported that a 12 hour with day/night rotation was associated with more prevalent visual problems and pain in the legs compared to 8-hour day shift workers. Johnson and Sharit (2001) found a 12-hour fast rotation associated with better perceived general health and fewer gastrointestinal complaints when compared with a fast 8-hour 3-shift rotation.

A study by Jaffe, Smolensky, and Wun (1996) compared an 8-hour group with an 12-hour group who worked a 4 (days)/4 (nights) rotation with 4 off-days between each shift change. In this study no differences in cardiovascular or gastrointestinal complaints between the groups were found. When the complaint groups were combined, eight-hour backward shift workers exhibited the highest score, the level of most complaints, in comparison to the 12-hour shift workers and day workers who had identical scores. In a Study by Tucker et al (1998) an early shift start (6 am) compared to a later one (7 a.m.) was associated with poorer self-rated health (i.e. GHQ-scores) and more cardiovascular problems, but not with more digestive problems. In the same study a 12-hour shift was associated with a higher level of self-reported pains and slightly more cardiovascular complaints and lower neuroticism. In contrast, the study by Tucker, Barton, and Folkard (1996) found more favourable results for 12-hour shift on similar outcomes.

There is some evidence indicating that working extended shifts may result in fatigue and recovery and an increased level of subjective complaints. Duchon, Smith, Keran, and Koehler (1997) reported findings before and after workers in an underground mine converted from a continuous 8-hour to a 12-hour rotating shift schedule. Heart rate measures suggested that the workers were able to adapt their work effort to longer shifts, while measures of mood and sleepiness responses and physiological recovery suggested more fatigue during 12-h shifts. Whether the fatigue related to long shifts has longitudinal effects on psychological of physiological health is not known. In a longitudinal study, comprising of ten years of working in a 8-hour shift followed by 10 years of 12-hour shifts the 12-hour shift workers reported fewer headaches and gastrointestinal complaints and fewer problems of alcohol misuse, while other illness complaints remained at a similar level (Lees & Laundry, 1989). In a 1-year follow-up of female electronic workers the 12-hour shift was associated with higher levels of tiredness and headaches but no differences in sickness absence rates was observed (Chan, Gan, & Yeo, 1993).

Studies comparing 8-hour and 12-hour shifts suggest that longer periods may not as such form a health risk. Most studies have reported some changes in fatigue-related functioning though. In addition, studies on long-term health effects of longer (e.g., 12-hour) shifts are very limited.

Offshore and onshore work

Offshore workers are "healthy workers", and a high medical standard is required of them, compared to onshore occupational groups. This makes straightforward comparisons of the groups difficult. Also, there is limited evidence on the effects of the combined effects of night shifts, long working days and several successive shifts over a longer period of time (e.g., two weeks), and therefore the health consequences of working long hours and long days intermittently with long weeks off duty are not well known.

In a study by Tuchsen and colleagues (2005) in which Danish bridge and tunnel construction shift workers who worked long hours and long weeks (typically 7 days with 12 hours, 7 days off-duty) were followed for death, hospitalization and outpatient or emergency ward treatment over 6 years. The overall mortality in the study cohort did not differ from that of all Danish construction workers, but they were more often treated in hospitals for various conditions such as infectious diseases, nervous diseases, circulatory diseases, ischemic heart disease and diseases of the digestive system.

Compared to day work, night shift work has been reported to predict a larger rise to increases in BMI among personnel working offshore in 12- hour shifts with a typical rotation patter of 7 night shifts and 7 day shifts followed by 14 days of shore leave (Parkes, 2002). In contrast to the findings showing that shift work may have various harmful effects on one's psychological and physiological wellbeing, shift work has not coherently been related to increments of sick leaves. In a study on chemical plant workers with more than 11000 episodes of sick leave lasting more than 3 days, no difference between shift workers and day workers was found (Kleiven, Boggild, & Jeppesen, 1998). Partial explanations for this may be that a large proportion of shift workers are a self-selected population and the persons who stay in shift work are the survivors. In concordance with this, the highest rates of sickness absences are reported among those who have previously worked shifts (Aanonsen, 1964, cited in Spurgeon, 2003), and mortality has been found to be increased in former shift workers in general (Knutsson et al., 2004). Consistent with the general findings of shiftwork, Parkes and Byron (2001) found that onshore and offshore installations personnel working day/night rotating shifts were more likely to report sleep disturbance and gastric problems than those working on day shifts. Moreover, the prevalence of other minor health problems did not differ between day-shift and day/night shift personnel in this study.

Twenty-seven % of the shift workers reported having had stomach problems during offshore period (the number was higher in women, 36 %) and 19 % were troubled by muscular tension (the number for women was 51 %) during the offshore period. The working hours 00-12/12-24 with and without rotation were most strongly associated with health complaints (Lauridsen et al., 1991). The associations of shift-work and health complaints such as psychological distress, gastric problems and headaches appear to depend to some extent on the job type (Parkes, 1999).

In a recent study, 36 % of the offshore workers reported recurrent muscular pain (Mearns & Hope, 2005). In data comprising of 1944 consultations in offshore conditions musculoskeletal and respiratory diagnoses (common cold etc.) were the most frequent (23 and 28 %). In the same study younger age groups had disproportionately more accident consultations, while older age groups were relatively more likely to consult for illness reasons. In maintenance workers the consultation rates were the highest for both illness and accidents, but accident rates were even little higher in construction (drilling personnel) workers. A similar finding applied to shift work: Shift workers had relatively high consultation rates for accidents, as compared with day workers, whereas the opposite was true for illness consultations. In offshore conditions shift workers also attended the sickbay more often, and were more likely to experience gastric problems (twice as much compared to day workers). The review by Parkes (1996) concluded that sickness absence rates in offshore workers appear to be lower than in the general work force which was not surprising as the offshore workers are healthier, selected, and regularly examined by practitioners. Moreover, in many cases short absences may not reliably appear in records.

There is evidence that working long hours may predispose to a development of mental and physical disturbances at least in some working groups, but these results are not directly applicable to long working times with long periods of recovery used in off and onshore oil industry. Some evidence comes from studies on 84 hours per week (12 hours/seven days, alternate weeks off) (Persson et al., 2003). A study comparing an ordinary 40-hour week and an 84-hour week in a group of men working longer hours per week in response to requests from workers did not find any marked changes in test performance, fatigue, and sleepiness (Persson et al., 2003), or biomarkers for stress and metabolic processes (Persson et al., 2006). However, the work load indexed by a heart rate measure during work was higher in the 40 hour group, a circumstance that may have affected the results. Also, there was a decreasing trend in the cortisol levels (Persson et al., 2003), and testosterone (Persson et al., 2006) during the work week in the 84-hour group. To sum up, there is limited evidence of more acute effects on the health effects of an 84-hour work week. However, its combined effects with shift work and other conditions and its longitudinal effects are not known.

Offshore and onshore male workers with similar jobs reported identical levels of minor health problems such as experienced pains, sleeping problems, gastroenterological symptoms and headaches excluding the level of anxiety which was higher in the offshore group. Gann et al (1990) found no differences in the mental health of offshore workers compared to onshore counterparts, while in the study by Cooper and Sutherland (1987) some signs of increased anxiety in offshore workers was reported. In addition, Parkes (1992) or Cooper and Sutherland (1987) did not find any differences between offshore workers and comparison groups for perceived health measured by the GHQ.

In a follow-up study of 104 production operators anxiety increased, possibly due to increased age and to an increased workload (Parkes & Razavi, 1996). This pattern was evident in both onshore and offshore workers. There was also a higher incidence of self-reported health complaints compared to normative data which may point to an increased health risk. In the same study (n= 82), longer shift work duration predicted poor self-rated health independent on prior health status, negative affectivity, age, and onshore vs. offshore location. When onshore and offshore workers were compared to normative data the operators working offshore had more headache and musculoskeletal problems than others.

Few empirical studies have examined the mental health of workers on North Sea oil and gas installations, and from the available literature it is unclear whether offshore employees show impaired mental health relative to their onshore counterparts. As compared with published data, only the onshore group showed low GHQ scores, although both groups were low in neuroticism (Parkes, 1992). Analysis of GHQ subscale scores demonstrated that anxiety was significantly higher among offshore workers than among those working onshore, but there were no significant differences in somatic symptoms or social dysfunction (Parkes, 1992). In a sample of 1472 males working offshore from all main occupational groups the overall stress level in offshore employees was reported to be lower than in a comparable sample working onshore (Parkes & Clark, 1997a). In the sample smoking was more frequent among offshore workers compared to onshore workers. A more general finding of the study was that shift work was related to higher self-reported gastric problems, and sleep disturbances.

Parkes and Byron (2001) compared onshore and offshore male workers in a sample of 909 participants. The offshore personnel reported a greater exposure to physical stressors bur a lower workload and higher work autonomy. Anxiety and somatic symptoms were higher among onshore personnel (adjusted for job types, companies, age and neuroticism). Gastric and musculoskeletal problems were more frequent in onshore workers, whereas the opposite was true for sleep disturbances. Offshore workers were more likely to be smokers (31 %) than their onshore counterparts (21%). Onshore workers in the age group under 50 years were more likely to have a higher BMI compared to offshore workers.

Sources of stress in offshore conditions may vary along with the educational level. In a study of 561 male offshore personnel, workers with higher education reported more stress arising from the interface between job and family and social life and less from ergonomics (Chen, Wong, Yu, Lin, & Cooper, 2003). In the same group of participants a 1-year occurrence of musculoskeletal complaints was common, and 56 % of the workers had at least one complaint. Maladaptive eating behaviors, perceived safety, physical environment of the work, and ergonomics were the most frequent predictors of pain in various body regions.

Parkes and Clark (1997b) reviewed the findings on possible effects of a three-week period offshore combined with a three-week leave period to the well being of offshore personnel. 190 participants were working in long tours. The longer tours, compared to the more common two-week tours, were generally rated as less satisfying, with the exception of a proportion of workers, mainly consisting of drilling personnel. The results of a small scale study with 55 participants did not reveal any significant differences in perceived mood, work load or sleep for two- and three- week tours (Parkes & Clark, 1997b).

To sum up, compared to onshore occupational groups, offshore workers are a selected group of workers and a high medical standard required of them. This makes straightforward comparisons of the groups difficult. The current limited evidence from studies focusing on long working weeks with long work days (84 hours), suggest that in men working on their own choice remarkable differences in their psychological or physiological stress responses are not to be perceived, but the evidence is far from conclusive. With a few exceptions, studies comparing onshore, offshore, and regular working populations have been cross-sectional and have focused on self-reported psychological and physiological symptoms. Some additional information comes from sick-leave records. The general findings from self-reported symptoms do not point to major differences in health of onshore and offshore workers compared to the general working population. Among contruction workers, a higher incidence of different type of diseases was found among oshore workers compared to other construction workers. Some shift rotas (e.g., 00-12 / 12-24) may be associated with a higher level of physical complaints.

Living habits

Shift workers have somewhat more unhealthy living habits than day workers, a characteristic also associated with observed differences in socioeconomic class. In general, shift work is related to increased smoking, higher triglyceride levels, and lower levels of HDL cholesterol, and an increased risk of weight gain and obesity. On the other hand, there is negative or inconclusive evidence for the relationship on shift work to blood pressure, blood lipids, physical inactivity and energy, protein, total fat, or carbohydrate intake (Härmä, 2006). The health habits of the offshore workers tend to be poor. For instance, the prevalence of smoking has been found to be higher among offshore workers than among their offshore counterparts and in general population (Mearns & Hope, 2005; Parkes & Clark, 1997a), and offshore workers are often more obese. Mearns and Hope (2005) reported that 52 % of offshore employees were overweighed, 12 % were obese, and the amount of overweight increased with age. The positive health behaviours were found to decrease with age. 32 % of the participants were current smokers and 27 % were former smokers. Good health habits associated with a good self-rated health, and also to perceiving the health climate of the working place as more positive. Mearns and Hope (2005) summarized the findings of health habits in offshore conditions by stating that a poor diet, a high prevalence of smoking, binge drinking patterns, overeating and a lack of exercise are common lifestyle problems in offshore employees. At the same time they reminded of the favourable effects of health promotion and life-style programs that have been introduced to alleviate to decrease the poor health behaviours.

3. RISK REDUCTION STRATEGIES ASSOCIATED WITH SHIFT WORK AND EXTENDED WORK PERIODS

3.1. Shift scheduling with a focus on extended work periods

3.1.1. The speed and direction of shift rotation

The speed and direction of shift rotation, as well as the distribution of free days within the shift system, have shown to be relevant factors in relation to shift workers' fatigue, sleep and long-term health. Human circadian rhythm is slightly over 24 hours making phase delays easier both in shift work and after time shift flights (westwards vs. eastwards flights). For example, as compared with forward-rotating schedules, backward rotating shift systems showed a relative risk of 2.9 for an increased need for recovery and a risk of 3.2 for poor general health (van Amelsvoort, Jansen, Swaen, van den Brandt, & Kant, 2004). The human circadian system is rigid, but it tries to adjust to a change in shift rotation. During the time of adjustment, the body stays in a state called "circadian disharmony", which also induces impaired performance and poor sleep. During the consecutive night shifts, the change in sleepiness is dependent on the possible circadian adjustment during the night shifts.

In very slowly rotating shift systems, including outdoor work and exposure to environmental light, more circadian adjustment (mostly by phase delay) takes place than in weekly or rapidly rotating shift systems (Härmä, 2000; Koller et al., 1994). In onshore work, circadian adjustment takes place among 30–50% of the shift workers (Härmä, 2000). Even if rapid adjustment takes place, time is again needed for the re-adjustment on rotating shift systems after the end of successive night shifts. Rotating shift work, especially the weekly rotating shift systems, are thus often related with sleep deprivation while in offshore work and with many consecutive night shifts and very slowly rotating shift schedules, even full circadian adjustment during consecutive night shifts has been described (Barnes, Deacon et al., 1998; Barnes, Forbes et al., 1998; Bjorvatn et al., 1998).

On rotating shift work, the very fast rotating shift systems (1-2 consecutive night shifts) have also proved to be more beneficial for sleep/wakefulness than the slightly slower rotating systems (3-5 consecutive night shifts) (Hakola & Härmä, 2001; Härmä & Kandolin, 2001; Härmä, 2006; Härmä & Ilmarinen, 1999). In a controlled intervention study (Härmä, 2006), we studied recently the effect of a very rapid forward-rotating shift system among young and older shift workers in a controlled intervention study. The use of the new shift schedule increased the main sleep length after the night shifts and improved alertness and psychomotor performance in relation to the night shift among the older (over 45 years) age group. Alertness improved during free time after the night shifts, and sleep complaints decreased after all of the shifts. The shift workers also reported a marked improvement in general health and social and family life during the new shift system.

3.1.2. Starting and ending times of the shifts

Shift schedules vary significantly in relation to how they offer time for recovery in relation to different shifts. If the time-off between shifts is less or even close to the average sleep need (7.5 hours), a full recovery is not possible. The use of "quick returns", in other words, the existence of a short time-off between evening and morning shifts, is frequent in many irregular shift systems. Quick returns are related to shortened sleep (Sallinen et al., 2003). On the other hand, the length of the shift worker's sleep is directly related to the occurrence of severe sleepiness during shifts (Härmä et al., 2002). A later starting time in the morning shift is important for the length of the previous night sleep. A controlled intervention study on a regular shift system indicated that a delay in the shift starting time resulted in an improvement in both sleep and wakefulness before the morning shift (Rosa et al., 1996). In an irregular shift system, each hour delay in the starting time of the morning shift is related to a 40- to 50-minute extension of the main sleep length (Sallinen et al., 2003). Also, the later the starting time of a night shift, the greater the likelihood of napping before the shift (Sallinen et al., 2003). Napping before and during night shifts cuts the time spent awake, and even short periods of sleep improve alertness and performance during the nigh shift considerably (Åkerstedt, 1998a; Härmä et al., 1989; Sallinen, Härmä et al., 1998). Too short a time-off interval or an early starting time for a night shift (like 18:00) makes napping before the night shift difficult.

3.1.3. Long work hours

Based on the literature search, we did not find any published intervention studies on extended work periods in oil industry, in which a change in work hours would have been studied systematically. However, there are some cross-sectional studies comparing the effects of different rotating systems on perceived health (Lauridsen et al., 1991; Parkes, 2002). The published field studies (Barnes, Deacon et al., 1998; Barnes, Forbes et al., 1998; Bjorvatn et al., 1998; Bjorvatn et al., 2006; Gibbs et al., 2002) also cover a large variety of different shift systems (7N-7D, 7D-7N, 14N/14D, 21N/21D), making the comparison between the individual studies possible.

Related to onshore work and much shorter average work hours, some studies have manipulated average work hours or overtime experimentally. Recently, the effects of overtime on stress reactions were studied by comparing a week of overtime with a normal week within the same group while controlling for workload (Dahlgren et al., 2006). The results showed that the week with overtime was associated with decreased sleep, more symptoms of fatigue and exhaustion, and an increase in sleepiness at the end of the week. There are some company-based interventions that have studied the effects of a reduction in workhours from 7 or more to 6 hours indicating mostly positive effects on social life, musculoskeletal problems and perceived health (Wergeland et al., 2003).

The main findings of the different offshore studies related to the findings from the rotating and non-rotating 12-hour shift system are described in Table 1. The general implications of the studies are:

7N-7D

Good circadian adaptation by the end of the night shift week, severe disturbances of sleep/wakefulness during the first day shifts. More problems of sleep/wakefulness and performance than in the 14N/14D.

7D-7N

Differences in circadian adaptation during the first night shifts depending on the time of the year. More problems of sleep/wakefulness and performance than in the 14N/14D.

14N/14D

During work periods, fewer sleeping problems, sleep debt, the use of sleeping pills, performance impairments and subjective health problems than in the rotating shift systems (7N-7D or 7D-7N) according to several studies. Full circadian adaptation by the end of the first night shift week and the adaptation of the sleep/wakefulness rhythm in few days. Less problems of sleep/wakefulness than in the 7N-7D or in the 7D-7N shift systems. 2 x times less circadian phase shifts

During days off, the recovery of sleep/wakefulness takes 4-6 days being, the time being longer than in the 7N-7D shift system in which re-adaptation takes place during the work hours.

Table 1. The main effects of the different 12-hour offshore shift systems on sleep and sleepiness, performance and health.

	Sleep and sleepiness	**Performance and operational risk**	**Health**
7N-7D	Full circadian adaptation by the end of the night shift week (Gibbs et al., 2002) Full adaptation of sleep/wakefulness by the end of the first night shift week. Severe disturbance of sleep-wakefulness during the following day shifts (Bjorvatn et al., 2006) More severe problems in sleep-wakefulness than in the 7D-7N and 14N/14D shift systems (Parkes, 2002)	Psychomotor and routine-like cognitive performance is impaired by two 12 h circadian changes and a significant loss of sleep (Parkes, 2002). Sleep loss from two 12 h circadian changes may lead to impairments in higher-ordered cognitive functioning such as in risk-taking behaviour (Killgore et al., 2006; O'Brien & Mindell, 2005; Roehrs et al., 2004). Potential advantage from adaptation of performance to night shifts during the 1st week cannot be utilised during the second week (Lamond et al., 2004; Parkes, 2002). Circadian disruption and sleep loss that impair cognitive functioning occur on each 14 day work period.	Peak of accidents during the first day of the shift, then decreased in the second week (Lauridsen & Tönnesen, 1990; Forbes, 1997).
7D-7N	Differences in circadian adaptation depending on the time of the year (Barnes, Forbes et al., 1998) The number of subjects not sleeping well offshore higher than in the 14N/14D (Lauridsen, et al., 2006) Impaired sleep/wakefulness compared to 14N/14D (Parkes, 2002)	Potential advantage of adaptation of performance to night shifts cannot be utilised (Lamond et al., 2004; Parkes, 2002). Sleep loss and circadian disruption that impair cognitive functioning occur on each 14 day work period.	Peak of accidents during the mid period of the shift, then decreased in the second week (Lauridsen & Tönnesen, 1990; Forbes, 1997).

14N/14D	Full circadian adaptation by the end of the first night shift week (Barnes, Deacon et al., 1998) Adaptation of the sleep/wakefulness within few days during the night shifts. Readaptation to day life in 4-6 days (Bjorvatn et al., 1998) Less sleeping problems and the use of sleeping pills compared to the weekly rotating shift systems (Lauridsen, et al., 2006). Lowest overall sleep deficit compared to the rotating shift systems (Parkes, 2002)	The level of psychomotor performance is quite even and acceptable through the 14 days work period, the only exception being the first night shifts in a row (Parkes, 2002). Sleep loss and circadian disruption occur on only every second 14 day work period, which is likely to decrease the harmful effects of sleep loss on higher-order cognitive functioning (Killgore et al., 2006; O'Brien & Mindell, 2005; Roehrs et al., 2004).	The peak of accidents during the first day after the change, then decreasing during the second week (Lauridsen & Tönnesen, 1990; Forbes, 1997). When 12-our 2- week schedules were compared, the fewest complaints were found among those on rotating 06-18/18-18-06 and highest among group without rotating 12-24/00-12 schedule
21N/21D	No significant change to the 14N/14D, but the 3rd week shows declining alertness	No studies.	The increased ratio of serious accidents per 3+ days accidents after two weeks on the installations (Parkes & Swash, 2000). 3-week tours compared to the 2-week tours, were rated as less satisfying (n =190) (Parkes & Clark, 1997b). No differences in mood, work load or sleep when compared to 2-week shifts (n =55) (Parkes & Clark, 1997b).

7N-7D - a rotating of 7 night shifts followed by 7 day shifts
7D-7N - a rotating of 7 day shifts followed by 7 night shifts
14N/14D - 14 night or 14 day shifts
21N/21D - 21 night or 21 day shifts

3.2 Occupational health care

3.2.1. General goals of occupational health care in shift work

Human beings belong to an originally diurnal species, biologically programmed to be active during the day and to sleep at night. However, in modern society many activities require continuous work inputs, leading to extended work periods and shift work. There are considerable individual differences in the ability to adapt to such irregularities. Good health, sound lifestyle, and social support promote adaptation to irregular work hours. Shift work is associated with more subjective health problems and psychosocial stress than working daytime and it increases the risk of e.g., cardiovascular diseases. Therefore, the challenges for the occupational health care are great. General goals of the health care in shift work can be listed as follows (Examinations in Occupational Health Services, 2006; Härmä, 2000b; Monk, 2005).

- evaluation of the baseline health condition
- screening of the cardiovascular risks
- informing about the health risks associated with exceptional work hours and means of prevention of the risks
- assessment of suitability of employees with symptoms or disorders which may become worse in shift work
- screening for factors (disorders, medications etc.) impairing vigilance
- follow-up of health condition and adaptation to shift work.

3.2.2. Specific aspects of occupational health care in petroleum industry

In addition to general goals the field of activity set specific requirements to the employees and also to the occupational health care. The work tasks and circumstances necessitate a correct ability to perform in order to minimize safety risks, including emergencies in difficult and dangerous situations offshore. Dormant, but possibly serious disorders should be identified in an early stage because in the case of medical emergency the delay to hospital treatment can be considerable especially when working offshore.

3.2.3. Current practices

Some key aspects of the current practices in the occupational health care in Norwegian petroleum industry were surveyed and a summary on the results of three companies is given in Table 1. Generally, the procedures seem to be quite identical. Only one company used a more detailed medical examination form but the guidelines of health requirements were similar.

The medical examination form (Norwegian Board of Health/ Rogaland County Medical Office) used in health evaluations includes a personal health statement by the employee and a medical certificate, consisting of clinical examination (with some laboratory tests) and an evaluation by the physician. In medical requirements there is a list of conditions that must lead to a conclusion of non-compliance with medical requirements, and a list that may lead to a similar conclusion. The first list includes criteria on vision, hearing, motor system, mental health, and risk of losing consciousness (including type 1 diabetes), as well as pregnancy after the 28th week. The second list includes a broad variety of medical conditions as well as the reference "Other conditions causing a person to be medically unfit". The examined person has the right to have the case considered by the Norwegian Board of Health.

In conclusion, the focus of the current occupational health care practises in Norwegian petroleum industry seems to be on finding out whether a person is medically fit to be on an installation in the petroleum activities.

Table 1. Features of current practices in occupational health care in three Norwegian petroleum companies.

	Criteria/assessment of suitability to shift work	Defined medical requirements*	Health evaluations	Special training of occupational health professionals	Material to promote adaptation to shift work	Controlled use of hypnotics
Company A	-	+	Every 2nd year	-	+	+ (zolpidem)
Company B	-	+	Every 2nd year	-	+	+ (extremely low use)
Company C	-	+	Certificate valid max. 2 years	Mandatory courses	+	+ (zopiclone)

* Given in the "Examination form - Medical examination of persons in the petroleum activities on the Norwegian continental shelf" by Norwegian Board of Health/Rogaland county medical office.

3.3. Timing of sleep

As sleep is one of the key determinants of alertness its optimal timing in relation to shifts is a countermeasure to extreme sleepiness. There are at least three identifiable issues worth considering in this context: i) the adaptation of the sleep-wake-rhythm to night shifts, ii) a napping strategy to alleviate sleepiness particularly at the end of the night shift, and iii) re-adaptation of the sleep-wake cycle to a day-oriented rhythm after a spell of night shifts.

The adaptation of the sleep-wake rhythm to several consecutive night shifts can be facilitated by delaying bedtime by 2-3 hours already before the first night shift in a row. This practice is particularly indicated when a work period begins with several consecutive night shifts after several days off. However, if a worker has to wake up early in the morning preceding the first night this practice is unworkable because, in this case, it leads to an acute sleep debt before the first night shift, which, in turn, exacerbates sleepiness in the shift.

During the night shift period, the sleep-wake rhythm can be reset best with exposure to an optimal light-dark cycle (see below) (Duffy, Kronauer, & Czeisler, 1996). In addition to this, day sleep, which is usually truncated to 4-5 hours despite accumulated sleep debt, can be prolonged to some extent by taking care of sleep hygiene. In practise this means that external sleeping conditions are free from noise, uncomfortable temperature and disturbing light. In addition, it is of importance that the sleeper is free from high physiological, emotional and cognitive arousal upon bedtime. This is at times a problem with the evening and night shifts due to a short period of time between the end of the shift and the start of the following sleep period. There are a number of relaxation and other techniques available which can be used to deactivate the mind and body before a sleep period. Too high an arousal can also be due to the use of stimulants such as caffeine too close to the next sleep period (see below). In this case, the introduction of proper behavioural instructions is in order.

Various napping strategies are perhaps the most important countermeasure to severe sleepiness at night work. Their role is of the utmost importance in the first night shifts during which the adaptation process of the circadian rhythms is still far from complete. One option is to take a prophylactic nap as close to the beginning of the night shift as possible, which decreases the build-up of homeostatic sleep pressure over the hours of continuous wakefulness (Dinges, Orne, Whitehouse, & Orne, 1987). This practise should be employed at least in connection with the first night shift. Napping prior to the next night shifts is also worth considering. In this case, the day sleep period can be split into two parts: the first part timed immediately after the end of a night shift and the latter part as close to the next night shift as possible. It is important to keep in mind that there is not only one optimal sleep-wake rhythm suitable for everyone, but rather there are various remedies of which the most suitable can be chosen through trial and error.

There are a couple of studies into the effectiveness of prophylactic napping in connection of night shifts. A field study, based on mathematical modelling, found that napping prior to a night shift was associated with a 38-48% decrease in highway vehicle accidents among shift-working police drivers (Garbarino et al., 2004). Results from a laboratory study were in line with the study of Garbarino et al. They showed that a 3 hour afternoon nap prior to a simulated night shift improved participants' psychomotor performance and EEG-based alertness while driving a car simulator (Macchi, Boulos, Ranney, Simmons, & Campbell, 2002).

Another napping strategy is to implement nap pauses into the night shift. Our own laboratory study revealed that a 30 min nap pause (about 20 min of sleep) placed either at 1 p.m. or 4 p.m. significantly reduced the proportion of lapses in a reaction time test at the end of the first night shift (Sallinen, Härmä, Åkerstedt, Rosa, & Lillqvist, 1998). A more recent field study examined the impact of a nap opportunity on performance and alertness in aircraft maintenance engineers during a 12 hour night shift (Purnell, Feyer, & Herbison, 2002). The main finding was that a 20 min nap taken between 01:00 and 03:00 improved vigilance performance at the end of the night shift during the first night shift but not during the second one. Self-reported sleepiness, either at work or while commuting was not affected by the nap. This finding suggests that an opportunity of taking a nap is particularly important in the first night shift.

Re-adaptation to a daytime oriented rhythm after a spell of night shifts can also be facilitated to some extent by an optimal timing of sleep, even though an optimal light-dark rhythm is the most influential means for this purpose (see below). One option is to limit sleeping to 2-3 hours immediately after the last night shift in a row and "save" the remainder of sleep pressure for the coming night. The limitation of day time sleep to a minimum is also recommendable for the next days off, keeping in mind, however, that daytime alertness is maintained at a reasonable level considering for example driving a car.

An Israelian study showed that elevated chronic sleepiness is associated with an increased rate of occupational injuries and even more interestingly that a simple intervention can improve the situation (Melamed & Oksenberg, 2002). The authors found that a questionnaire based assessment of sleep and sleepiness combined with a 90 minute lecture on sleep and sleep disorders, a letter on the results for the treating physician, and a recommendation to visit a sleep disorders unit if elevated sleepiness resulted in a clear drop in injuries among the sleepy workers. In fact, the percentage of injuries among those who showed elevated sleepiness in the initial assessment decreased to the level of the workers with normal alertness during the next year.

3.4. The use of bright light

It is well acknowledged that timed exposure to bright light facilitates the circadian adaptation to night work (Czeisler & Dijk, 1995; Czeisler et al., 1990). The effect is dependent on the exact timing of the light and darkness exposure in relation to the endogenous body clock, the optimum area for phase delays being just before the body temperature minimum normally around 5 a.m. On the other hand, exposure to bright environmental morning light is related to slower circadian adaptation to night work, as measured by the adaptation of e.g., salivary melatonin and cortisol rhythms (Koller et al., 1994). The circadian adaptation speed and the optimal timing of bright light are also individual making the use of bright light difficult. In addition to bright light, melatonin has phase shifting properties, too. These effects are, however, not as strong as those with bright light.

The use of bright light to alleviate the circadian adaptation by offshore workers has been investigated in two studies by Björvatn (Bjorvatn, Kecklund, & Åkerstedt, 1999; Björvatn et al., 2007). In the first study, the use of bright light in the 14N/14D shift system at an oil platform of the North Sea was tested. Bright light treatment of 30 min per exposure was applied during the first 4 nights of the night-shift period and the first 4 days at home following the shift period. The bright light exposure was scheduled individually to phase delay the circadian rhythm. Based on the results, bright light treatment modestly facilitated the subjective adaptation to night work, but the positive effect of bright light was especially pronounced during the re-adaptation back to day life following the return home. The modest effect of bright light at the platform was, possibly, related to the finding that the workers seemed to adapt to night work within a few days even without bright light. In the second study (Björvatn et al. 2007), the use of bright light or melatonin in the 7N-7D shift system among offshore workers was evaluated. In a randomized controlled crossover design, the shift workers received placebo, melatonin (3 mg, one hour before bedtime) or bright light (30 min exposure, individually scheduled) during the first four days on the night shift and during the first four days on the day shift. Based on the results, melatonin modestly reduced sleepiness at work during the day shift and increased sleep with 15-20 minutes per day. Bright light gave values in between melatonin and placebo, but with few significant results. On objective measures, bright light improved sleep to a minor degree during the night shift. Hardly any side-effects were reported.

These results suggest that short-term bright light treatment helps the adaptation and especially the re-adaptation process in the 14N/14D shift system. In the 7N/7D system the effects of both bright light and melatonin were modest. The exact timing of the bright light and melatonin in different phases of the trips need further research.

3.5. Physical activity

Based on a meta-analysis, both acute and long-term physical activity have beneficial effects on sleep (Kubitz, Landers, Petruzzello, & Han, 1996). Physical fitness decreases shift work related sleep problems and may also have some phase shifting effects on the circadian clock. In an older series of studies by us, it was first showed that physically fit subjects had lower heart rates at work, less perceived exertion, lower orthostatic tolerance and faster recovery after the work not only during the day but also during the night (Härmä & Länsimies, 1985). In an intervention study with a match pair design the effect of physical conditioning to adaptation to shift work was later studied (Härmä et al., 1988a, 1988b). Significant increases in maximal oxygen consumption and muscle strength were achieved by a 4-month programme of 2 to 6 training sessions per week in the experimental group. Following from this, the increased physical fitness did not increase circadian adjustment to shift work. However, the exercise group reported a significant decrease in general fatigue (from 20.8 % to 4.3 %), particularly during the night shift, a decrease in the musculoskeletal symptoms and an increase in sleep length. No significant changes took place in the control group. The literature on the role of exercise as a sychronizer of human circadian rhythms has been discussed recently (e.g., Atkinson, Drust, George, Reilly, & Waterhouse, 2006; Reilly et al., 2006). The literature suggests that nocturnal exercise can induce phase delays. Reports of exercise-induced phase advances of the melatonin rhythm are rarer. In mechanistic terms, the lack of agreement with the phase-shifting effects of bright light suggests that exercise is not exerting its effects via photic entrainment pathways. In conclusion, physical fitness seems to decrease sleepiness, probably due to improved sleep and physical exercise at night may fasten circadian adaptation to night work.

3.6. Pharmacological measures

3.6.1. Stimulants

An extensive review on the use of stimulants (including caffeine) during sleep loss has recently been published (Bonnet et al., 2005). This Task Force report concludes that in situations in which extended wakefulness is necessary and sleep must be curtailed, limited use of stimulant medication may be appropriate on voluntary basis and under medical supervision. In most situations caffeine (from doses of 75 mg) can provide significant improvement of alertness and performance.

3.6.1.1. Caffeine

Caffeine is probably the most used stimulant in the world, usually taken in coffee, tea or cola soft drinks, but also available as tablets. The effect of caffeine is well documented: it improves alertness and performance at doses of 75-150 mg after acute restriction of sleep and at doses of 200-600 mg after a night or more of total sleep loss. The pharmacological half-life of caffeine is 3-6 hours, which is also the usual period for the stimulatory effect, and after a single dose it takes up to 24 hours until the pharmacological effect (possibly interfering with one of the sleep-promoting mechanisms in the brain) totally ceases. There are considerable individual differences in the sleep-interfering effect of caffeine, but excessive amounts (more than about 5-6 cups coffee or 500 mg caffeine per 24 h) may lead to pronounced variation of vigilance during wakefulness, and possibly negative effects on mood and performance. It has been estimated that up to 10 % of adults develop caffeinism, which can include restlessness, nervousness, excitement, diuresis, gastrointestinal disturbance, muscle twitching, rambling speech, tachycardia and agitation. Caffeine may also have major disruptive effects on the sleep if taken less than 8 hours before the beginning of the sleep period. In situations involving extended sleep loss (more than 2 nights) a single dose of 600 mg of caffeine has been assessed to be roughly comparable to (but not as long lasting as) a single 20-mg dose of d-amphetamine or a single 400-mg dose of modafinil.

3.6.1.2. Medications

The use of amphetamines and amphetamine-like stimulants is mainly restricted to hypersomnias of central nervous system origin, which can be considered as a contraindication for shift work in safety critical occupations.

During the last few years the use of a non-amphetamine-like stimulant modafinil in shift-work sleep disorders has been investigated, and in the U.S. it has been approved by FDA for clinical use also in this indication. Modafinil in doses of 100-400 mg improves psychomotor performance, alertness and mood during sleep loss periods of up to 85 hours. It is usually well tolerated, with headache, nervousness and insomnia as the most common side-effects. Modafinil reduces sleep initiated within 14 hours of administration. However, there are indications that modafinil may impair the subjects' self-assessment of performance, leading to "overconfidence". Additionally, it raises body temperature, which may increase the risk for heat injury in heavy work and/or if wearing protective clothing.

3.6.2. Hypnotics

Modern hypnotics (both traditional benzodiazepines and the "newest generation", so-called z-medications zopiclone, zolpidem and zaleplon) act as benzodiazepine receptor agonists and enhance the effects of GABA, the main inhibitory transmitter in the brain. Although these compounds are generally non-toxic and well-tolerated, they also have considerable drawbacks, most notably tolerance (leading to loss of effect), addiction, abuse potential, and increased risk of traffic and other accidents. These problems, often associated with long term use, are quite well known.

On the other hand, less attention has been paid on the acute adverse effects of hypnotics. They are mostly associated with the "hangover" phenomenon, e.g., a residual daytime sleepiness and impairment of psychomotor and cognitive functioning the day after bedtime administration of a hypnotic (Vermeeren, 2004). However, the severity and the duration of these effects vary considerably between hypnotics, and they are strongly dependent on the half-life of the compound, dose level, and the time of administration.

In many countries the z-medications have largely replaced the benzodiazepines as hypnotics, as they are generally considered probably less addictive and - because of the shorter half-lives - usually have fewer "hangover" effects. The popularity of the short-acting benzodiazepines (midazolam and triazolam) has decreased because they not uncommonly cause confusion, automatisms, and rebound anxiety. In a standardized highway driving performance test, there were no residual effects of zaleplon (half-life 1 hour) of 10 or 20 mg about 5 hours post-administration, but zolpidem (half-life 2 hours) of 10 mg impaired the performance similarly as blood alcohol concentration (BAC) of about 0.7 g/litre. When tested 10 hours post-administration, zolpidem 10 mg had no residual effects, but zopiclone (half-life 5 hours) 7.5 mg impaired driving as much as BAC 0.6-1.0 g/litre (studies reviewed by Vermeeren, 2004).

3.6.3. Melatonin

Melatonin is the most used chronobiotic, i.e. a substance that can adjust the timing of internal biological rhythms. In a review of chronobiotics (Touitou & Bogdan, 2007) it is concluded that the use of melatonin to alleviate the effects of shift working depends upon the kind of rotation: slow rotations (e.g., 7 days) call for a phase delay to improve day-sleep duration and quality and nocturnal alertness and efficiency at work, whereas in fast rotations in which adaptation is undesirable, the use of melatonin may help in inducing sleep prior to night work without shifting the circadian phase. However, optimizing the dose, formulation and especially the time of administration require further studies (Touitou & Bogdan, 2007).

In conclusion, continuous or frequent use of medications is not advisable. If occasionally a hypnotic is needed, it is recommendable to choose a compound with short half-life and a low risk of residual effects after a usual sleep period. Most persons (can) use low to moderate doses of caffeine as a stimulant, but even this may have a (long lasting) disruptive effect on sleep.

4. DISCUSSION ON PARTICULAR RISKS AND RISK REDUCTION STRATEGIES RELATED TO WORK TIME ARRANGEMENTS IN THE PETROLEUM INDUSTRY IN NORWAY

Fatigue management is an essential part of risk reduction strategies at work, as many of the human errors having harmful aftermaths are associated with fatigue. To have a strategy for reducing fatigue, it is necessary that both employers and employees are aware of the risks associated with fatigue in their organisation, the sources of fatigue, and the means to alleviate the problem in practice. The next step is to turn this awareness into action. There are a number of measures related to shift arrangements, tasks, environmental factors at work, and non-work issues through which fatigue-related risks can be lowered. In earlier chapters, the risks and risk reduction strategies have been reviewed in detail. Here, we discuss the use of the most promising risk reduction strategies related to fatigue management and work time arrangements in the petroleum industry of Norway. The chapter will discuss the change of shift arrangements, occupational health care actions, and individual coping strategies as countermeasures to fatigue and ill-health.

4.1. Shift scheduling

The rather surprising discrepancy of this review is that while shift work and also partly overtime are obviously related with increased health risks (like fatigue and shortened sleep but also cardiovascular, gastrointestinal and mental diseases, type II diabetes and accidents), the few existing studies on extended work periods do not show a marked increase in fatigue and ill-health compared to shift systems with shorter average work hours. On the other hand, we could not find any studies comparing the effects of the 14N/14D "offshore" shift system between onshore and offshore workers.

The unexpected low amount of reported health problems among shift workers with extended work periods may be explained by at least three major possibilities. First, the workers on installations with extended work periods mostly stay on the sites on a contemporary basis making it relevant and highly motivated to work for long working days and for long periods to gain, respectively, longer periods of compensatory leave. The distant work sites do not offer many free-time attractions making a voluntary choice of long working days but also sufficient sleep and recovery during the time-off periods easier than among shift workers who do daily commuting. Secondly, adaptation to shift work is highly individual and some groups of petroleum industry workers, like those working offshore, may be highly selected. Finally, physiological adaptation to permanent night work is easier in oil rigs than onshore.

The offshore 14N/14D shift system was related with fewer sleeping problems, impaired performance, sleep debt, the use of sleeping pills and subjective health problems than the weekly rotating "swing" shift systems. However, re-adaptation at home was somewhat more difficult in the 14N/14D shift system than in the weekly rotating shift systems. Several studies on shift work with normal weekly work hours show that only a minority of shift workers can adjust their circadian rhythms to consecutive shifts systems, while almost a full circadian adaptation seems to take place in offshore night work. It is well known that the ability to adjust to consecutive night shifts is mostly dependent on the exposure to bright environmental light. In offshore work, workers are not exposed to bright environmental light during their free-time or commuting (which does not take place during the 2-3 week work periods). Conditions during onshore extended work periods are quite different, and there is no evidence that in these circumstances similar circadian adaptation to consecutive night shifts is possible.

It should be noted that performance, operational safety and the health of offshore workers is dependent not only on the used shift systems but also on the interaction of shift systems with other work demands, such as the amount of physical work load and environmental and safety hazards. Special emphasis should also be paid on the amount of overtime work. Considering the already long work hours, the use of overtime increases work load and occupational exposures to chemical or other environmental hazards. The acceptable international risk levels are normally based on average 8 hour working days. Also, sectors with a higher accident risk, like construction work common in both onshore and offshore work, are most vulnerable for the effects of long work hours on fatigue and occupational safety. We found limited strong evidence on the effects of two vs. three week extended work periods offshore on the performance, safety and health of the workers. Concerning the large individual differences in circadian adaptation, the extension of the stay period from two to three weeks may include additional risks for performance, health and safety. Additional research and carefull evaluation of the possible use of three week extended work periods offshore is needed.

In cases of a need to change a shift system, the introduction of new working times should be made by participative planning. Extended or flexible work hours are often introduced to match the needs of companies for longer operating and service times; work hours are thus company-controlled. However, work hours can also meet the needs of employees. In families with small children, the needs of parents are often different from those of younger or ageing employees. In distant work sites with limited possibilities for free-time, long work hours are often desired. Work hours can and should also be individually flexible. Participatory planning of work hours should include the negotiation, agreement and follow-up of an employer, employees, safety and occupational health representatives on the changes in work hours. Good practise includes a test trial of the new shift system for an agreed time period and an agreed way to evaluate the effects of the new shift systems on operational needs, health and safety. If the new shift system supports operational performance, is legal and does not risk the health and safety or the employees, transition to the new shift system can be decided directly by a vote of the employees after the test trial.

4.2. Occupational health care

The current occupational health care practises in Norwegian petroleum industry are focused on the evaluation of medical fitness to work in the petroleum activities, i.e. the aim is to identify major diseases and health problems, which could be a contraindication for the work mainly from the safety point of view. As it is well established that shift work is associated with an increased risk of several diseases (e.g., cardiovascular disorders) and, based on this review, the health habits of at least offshore workers tend to be poor, the practices should include preventive aspects as well as provide measures to promote adaptation to shift work.

The literature showed that both hypnotics and stimulants (caffeine) are used widely among shift workers. If sleeping problems are long-lasting and severe, affecting waking performance, the possibility to use cognitive-behavioural treatments for insomnia should be considered. Hypnotics should only be used occasionally when especially needed or during short periods, and preparates containing zaleplon or zolpidem are preferable, as the risk of adverse effects following the sleep period is lower.

4.3. Individual coping mechanisms

The studies on the use of bright light are promising indicating that a high potential for short-term bright light treatment alleviates the circadian adaptation offshore and the re-adaptation process onshore after the longer periods of night work. The use of melatonin and correct timing of sleep, nutrition and pharmacologic aids can be also well combined to the use of bright light both offshore and onshore after the trips.

Since the bright environmental light can affect the circadian process offshore either positively or negatively, the timing of bright light should be planned well. It is probable that outdoor workers and workers with heavy physical work are the groups needing most individual health education on the use of individual coping mechanisms to fasten the adaptation to night shifts and the adaptation to day-oriented life after the offshore journeys.

As to timing of sleep, the most promising countermeasure to sleepiness is the implementation of an opportunity for napping in the night shift. The napping strategy seems to be most important in tasks requiring a high level of vigilance as well as in tasks with high demands for decision making.
In addition to napping during the shift, the recommendation of napping close to a night shift (especially the first one) seems to be a reasonably effective measure to support functional capacity during the early morning hours. A third aspect of importance is to take care of sleep hygiene including proper sleeping conditions during the nap and the main sleep period. The manipulations of the sleep-wake rhythm as a means to enhance phase-shifting of the circadian pacemaker do not seem promising; the changes of the sleep-wake rhythm rather follow phase shifts of the circadian system.

5. RECOMMENDATIONS FOR IMPLEMENTATION OF CURRENT KNOWLEDGE AND STRATEGIES FOR FURTHER RESEARCH

5.1. Recommendations for the implementation of current knowledge

This review aims at detecting risk factors and risk reduction strategies associated with night work with the focus on extended work periods. The focus, as requested by the PSA, was on health and safety issues. Although a wide area of research was reviewed, there is still a considerably lack of information in some areas. Since our recommendations are based on the existing data, firm recommendations can not be given on all topics.

5.1.1. Extended work periods

1. to support work-site sleep/wakefulness, performance and occupational safety, we recommend that permanent shift systems (e.g., 14D/14D) should be preferred in offshore work compared to the weekly rotating shift systems
2. in both offshore and onshore work overtime work should be avoided during the extended work periods. This can be done for example by increasing reserve. Especially, overtime should be reduced among workers with particularly demanding working conditions (with high physical or mental workload).
3. in both offshore and onshore work the amount of safety-critical tasks at night should be reduced as much as possible
4. employer should support safe commuting after extended work periods

5.1.2. Occupational health care

1. systematic practises should be used by all companies
2. more emphasis on screening of chronic health risks (especially cardiovascular).
3. intensified screening for sleeping and vigilance problems at an early stage, and evaluation and treatment guidelines with the emphasis on non-pharmacological measures, to prevent short-lasting problems evolving to chronic cases
4. more frequent visits and check-ups than every 2nd year during the 2 first years for those with health problems and those aged >50 years. Counseling and follow-up after the first periods offshore
5. systematic education/courses for employees to promote adaptation to shift work and extended work periods
6. guide on sleep, coping methods (including light therapy, diet, physical activity etc.), effects of shift work on health and performance
7. special courses and education for health care professionals concerning the occupational health care in oil industry

5.1.3. Individual coping mechanisms

1. providing the employees with facilities to nap before the first night shifts
2. implementation of opportunities for short naps during the first two night shifts
3. support for the possibilities to use bright light after the end of consecutive night shifts at home to fasten re-adaptation to normal daily rhythm
4. Increasing healthy living habits in remote work sites through health promoting campaigns, tailored courses, individual /group counseling.

5.2. Recommendation for further research of extended work periods

1. Accidents research

The accident statistics is the basis for safety work on the offshore oil and gas industry. The statistics nowadays do not include the information of work arrangements of an injured worker. Thus it is not possible to analyze the effect of different shift systems on safety. Because near accidents are the same type of situations as real accidents but without personal injury, the registration of near accidents will also give an important information of dangerous situations. The other topic of further research is the effect of overtime on accidents, because information on working over 12 hours or over 14 days is deficient.

2. Epidemiology

The number of field studies showing differences between the particular shift systems is considerable and there are some cross-sectional questionnaire studies showing differences in perceived health. However, there is at the same time almost a full lack of good-quality prospective epidemiologic studies on the effects of different shifts systems and extended work periods on the risk for objectively defined diseases and occupational accidents. Previous studies have highlighted several sources of health hazards in onshore and offshore conditions which are the salient targets of future studies (e.g., shift-work, shift-systems, work stress, health habits, job type, combining of the working and domestic life).

The approaches of studies may be classified roughly into two categories of research both of high importance a) studies following the development of psychological and physiologic health of the employees, b) testing the effects of interventions aiming at reducing the suggested health risks.
In addition, it is highly important to collect data in a systematic manner and to include data from several sources, including self-ratings, physiological measures, and medical record data. A good example of a such multidisciplinary longitudinal approach can be found in the *10-town study*, in which all the public sector employees of ten Finnish towns have been followed systematically with a data collection interval of two years (http://www.ttl.fi/Internet/English/Research/Research+database+TAVI/naytaProjekti?id=801639&type=Research%20project).

3. Experimental studies

Shift work studies on the performance of real or one-to-one simulated work tasks are needed. This need stems from the fact that the existing results on the effects of shift work on performance are somewhat contradictory and it also seems that these effects can be, at least to some extent, task-specific. In addition, the shift schedules and environmental conditions of the offshore and onshore workers of the oil and gas industry are quite different to their colleagues in other industries. This difference calls for studies on work performance carried out in the shift systems and the environmental conditions of the offshore and onshore workers.

Since the extended work periods of the offshore workers are already used on onshore worksites it is recommendable that their suitability be carefully examined with proper experimental study designs. This recommendation is mainly based on differences in the environmental conditions and the tasks of the offshore and onshore sites.

4. Individual differences

As the shift schedules of the offshore and onshore workers are usually quite demanding for example in terms of weekly work hours and the number of consecutive night shifts it is recommendable that the individual characteristics favourable and unfavourable for adaptation to these demands are known. The role of aging on adaptation to onshore and offshore work should be studied. Even if the characteristics were not used as selection criteria they could be used i) to follow persons with a low adaptive capacity intensively enough and ii) to provide them with proper support by their occupational health care units.

Due to the exceptional psychosocial characteristics of the offshore and onshore worksites it is worth examining which personal and social life related factors facilitate or counteract psychosocial adaptation. Although there is some information on especially the use of bright light to support circadian adaptation, it would be of importance to have more research-based knowledge of different practical measures that would ease adaptation. The latter objective calls for intervention studies to be carried out.

5. Occupational health care

There is a need for research on the factors and causes as to why the employees have stopped working in the petroleum industry (including those that have led to the conclusion of medical non-compliance), to get information for further development of the evaluation of suitability and on the methods to promote adaptation to this type of work. In order to improve occupational safety and health, there is a need for research related to the follow-up and analysis of accidents, near-accidents, and departures from practise to assess the role of medical disorders or symptoms in such incidents.

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