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Seafarer fatigue: a review of risk factors, consequences for seafarers' health and safety and options for mitigation

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ABSTRACT

Background: *The consequences of fatigue for the health and safety of seafarers has caused concern in the industry and among academics, and indicates the importance of further research into risk factors and preventive interventions at sea. This review gives an overview of the key issues relating to seafarer fatigue.*

Materials and methods: *A literature study was conducted aiming to collect publications that address risk factors for fatigue, short-term and long-term consequences for health and safety, and options for fatigue mitigation at sea. Due to the limited number of publications that deals with seafarers, experiences from other populations sharing the same exposures (e.g. shift work) were also included when appropriate.*

Results: *Work at sea involves multiple risk factors for fatigue, which in addition to acute effects (e.g., impaired cognition, accidents) contributes through autonomic, immunologic and metabolic pathways to the development of chronic diseases that are particularly prevalent in seafarers.*

Conclusions: *Taking into account the frequency of seafarer fatigue and the severity of its consequences, one should look into the efficacy of the current legislative framework and the industry's compliance, the manning of the international merchant fleet, and optimised working, living and sleeping conditions at sea. Considering circumstances at sea, e.g. working in shifts and crossing time zones, that cannot be altered, further assessment of the potentials of preventive interventions including fatigue prediction tools and individual fatigue mitigation management systems is recommended.*

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Key words: fatigue, seafarers, risk factors, acute effects, chronic health effects, prevention

INTRODUCTION

Fatigue in a medical sense represents a state of physical and/or mental weakness and is affecting everyone, regardless of occupation and cultural influences, but it is also a symptom accompanying numerous diseases and one of the most frequent reasons for seeking medical attention [1]. At the same time, however, fatigue is particularly linked to specific circumstances of work.

Fatigue and sleepiness are often used as synonyms but differ because sleepiness will always end with a sufficient amount of sleep while this is not the case for fatigue, which has also physical aspects involved. Physical fatigue follows prolonged periods of physical activities and causes weakness and reduced endurance. Mental fatigue is mainly the consequence of mental stress and emotional exhaustion, or high workload such as long working hours. In particular disruption of the sleep-wake cycle and circadian rhythm, which is occurring in jet lag and shift work, causes irregularity of work and sleep and reduces the amount and quality of sleep between work cycles. Mental fatigue occurs gradually

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and insidiously, and may appear as cognitive impairment, reduced performance, mental symptoms such as a sense of weariness, and reduced alertness. The International Maritime Organisation (IMO) defines fatigue as "a reduction in physical and/or mental capability as the result of physical, mental or emotional exertion, which may impair nearly all physical abilities including: strength; speed; reaction time; decision making; or balance" [2]. We suggest a feasible definition as "a progressive loss of mental and physical alertness possibly ending in sleep".

Work-related fatigue is particularly an issue in safety sensitive occupational sectors, such as transportation (both at land, sea and in the air). The consequences of work-related fatigue have been widely studied in occupational settings. Many experiences from land-based trades such as road and rail transport as well as from air transport can be extrapolated to the maritime context [3].

The maritime industry is characterised by the necessity of seafarers to work in shifts to keep the vessel going continuously. Various forms of shifts have been applied, but common to most of them is that shifts permit less sleep because they break up the day in portions that leave insufficient time for rest and restitution. Sleeping may take place under unfavourable circumstances due to continuous exposures such as noise, vibration, movements of the ships and other disturbing factors at sea. Consequently, the quantity and quality of sleep is prone to be disfavoured, which is even worse if being forced to sleep at unfavourable times of the day when working outside the regular daytime hours [4].

The work patterns and life on board vary enormously according to factors such as cargo, type of trade, the crew nationality and flag state and so does the extent of fatigue. Working in the short sea sector appears to cause more fatigue due to more port calls and the associated increase of workload [5]. Compared to shore based workers, seafarers report higher levels of lethargy and poor quality sleep [6]. It is, however, impossible to globally estimate the extent and impact of fatigue on seafarers. Previous studies suffer from low response rates and consequently it is difficult to compare with the fatigue rate of the general population. However, patterns of day to day changes in fatigue have been shown to be measurable and vary considerably among particular subgroups of seafarers and between the start and end of voyages [7]. There is evidence of under-recording of seafarers' working hours, and that this may be related to cultural and commercial pressures [8, 9].

Measuring fatigue is complicated because fatigue represents an integration of subjective perceptions, performance and physiological functioning. The lack of a universal tool to measure fatigue challenges research that aims to relate fatigue to health and safety outcomes. However, subjective rating of sleepiness by the Karolinska Sleepiness Scale (KKS) is a simple approach for which there is a high validity on comparison with electroencephalographic and behavioural variables [10, 11]. KKS may therefore represent a feasible proxy for fatigue, and has shown its value in several studies on fatigue [11–18]. It is, however, emphasized that subjective rating of sleepiness differs from the subjective rating of performance [19]. Sleepiness has been shown to be context-dependent [20] meaning that sleepiness can be regarded as the lack of ability to maintain a wakeful state of attention without the aid of situational factors. Consequently, the context of sleepiness may influence the KSS rating [12]. Sleep diaries can serve as a proxy for the amount of sleep, while actigraph monitoring, which is applicable at sea, or electroencephalographic recordings represent a more objective measure of sleep, but cannot provide information as to what extent the person is suffering from fatigue.

A variety of specific fatigue measuring instruments, however, exist, as reviewed by Dittner et al. [21]. The majority of these currently available tools have the problem that they are aimed to measure fatigue in very specific medical circumstances such as in people suffering for instance from specific medical conditions for which symptoms include fatigue. This makes the majority of these instruments unsuitable for Measuring Fatigue in a Potentially healthy population such as seafarers. To our opinion, one of the more suitable available scales to measure fatigue is, for instance, the Multidimensional Fatigue Inventory (MFI-20) developed in 1995 by Smets et al. [22] for measuring fatigue in cancer patients, and this instrument has also been validated in healthy volunteers [23] The scale consists of 20 items, to be agreed upon on a 1 to 7 scale, divided over five dimensions of fatigue, namely 1) general fatigue, 2) physical fatigue, 3) mental fatigue, 4) reduced motivation, and 5) reduced activity.

This review aims to describe the causes of work-related fatigue in seafarers and the associated acute and chronic consequences of fatigue and risk factors for fatigue. The issue is complex. A simple illustration of the major relationships is provided in Figure 1. In addition, ways of mitigating fatigue will be discussed.

RISK FACTORS FOR FATIGUE

Studies of risk factors for seafarer fatigue may address either of the acknowledged maritime risk factors or their combination, or the occupational risk factors for fatigue that have been demonstrated among workers other than seafarers.

In a questionnaire study of seafarers, symptoms of fatigue were found related to a range of occupational and environmental risk factors at sea (sleep quality, work hours and shifts, tour length, job demands, work stress, sleep disturbances, time zone crossings etc.). The rate of fatigue

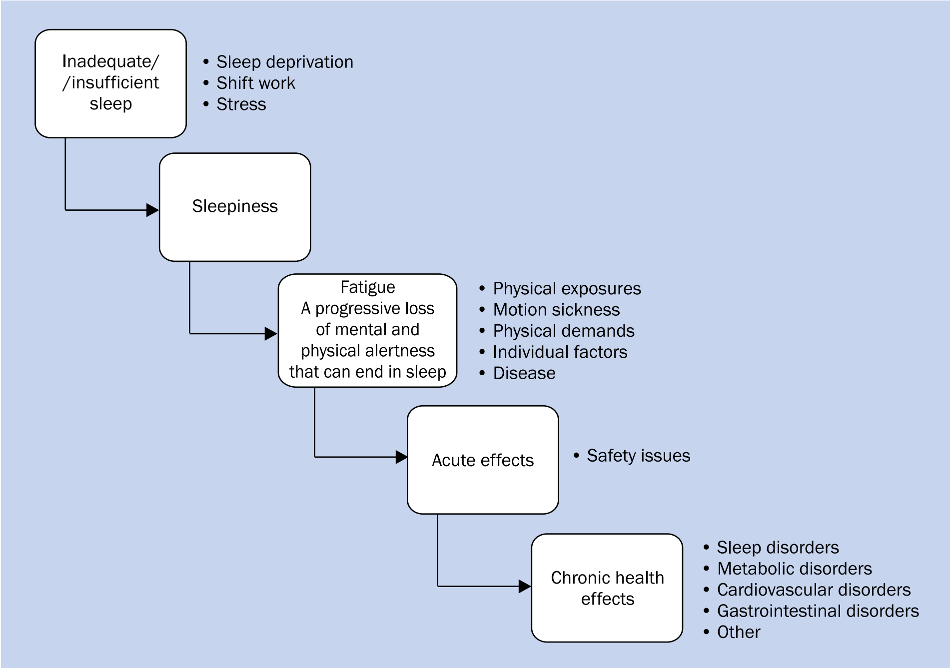

Figure 1. Diagram illustrating the main determinants and outcomes of fatigue

correlated with the amount of risk factors as well as with poorer cognitive and health outcomes with fatigue as the most important risk factor for the latter [24]. Other recent studies confirmed that these factors in combination must be considered to understand fatigue at sea, and emphasized that working more than 2 × 6 h per 24 h should be avoided since this leads to considerably high levels of sleepiness [25]. In a study of a representative Swedish sample of 58,115 individuals interviewed at regular intervals over a period of 20 years on issues related to work and health, Åkerstedt et al. [26] found that significant predictors for fatigue were female gender, age below 49 years, high socioeconomic status, present illness, hectic work, overtime work, and physically strenuous work.

Seafarers in the merchant fleet are the most studied among maritime workers. However, there is evidence that at times fishermen may be even more prone to fatigue. A review of fatigue in fishermen resulted in 5 studies that all confirmed fatigue to represent a serious risk in the trade [27]. One study of fishermen showed that 23% of days at sea permitted less than 4 h sleep, and understandingly the fishermen's perceived fatigue rating remained high after sleep [28]. In another study, 60% of fishermen believed that their personal safety had been at risk due to fatigue at work, and 16% had been involved in a fatigue related accident. 44% said that they had worked to the point of exhaustion or collapse [29].

Work stress, shift work and physical workload are among the most important risk factors that are related to fatigue [26, 30]. Sleep deprivation, rather than perceived sleep quality, correlates best with observed biological and metabolic changes. Most studies on the association between sleep and health are based on sleep length [31–33] but there is an increasing number of epidemiological studies on the association between sleep quality and health [34]. A causal relation is indicated by experimental demonstration of adverse health effects following a significant reduction of the sleep duration [35, 36].

STRESS

When it comes to the effect on sleep and fatigue of psychosocial work characteristics, the picture is complex. Unfavourable psychosocial work characteristics have only minor effects. While high job strain is found to be associated with difficulties initiating sleep and reduced psychomotor vigilance during night shifts, the average sleep duration and efficiency was not affected [37]. A literature review on psychological stress in seafarers concluded that seafaring is associated with mental, psychological and physical stressors with the most important stressors being separation from family, loneliness on board, fatigue, multi-nationality, limited recreation activity and sleep deprivation. The stressors differed in between strata and departments on board. The associated mental health risks are suggested to be addressed by helping seafarers to lower their stress level and to develop strategies for coping with "inevitable" stress conditions [38]. The social situation and stress at work are strongly linked to disturbed sleep and impaired awakening. Gender and age may modify these relations and the inability to stop worrying about work during free time seems to be an important link between stress and sleep [30]. Increased stress/worry at bedtime, for instance about work, is associated with impaired sleep [39], and work stress is typically associated with increased sleep latency due to work rumination [40].

A recent review found only a small to moderate effect of work demands and job control on sleep quality [41]. A longitudinal study of the relation with job demands and job control demonstrated that a transition from a non-high-strain towards a high-strain job was associated with a significantly reduced sleep quality and increased fatigue, while the opposite transition improved sleep-related problems [42]. This is in line with the outcome of a study of the influence of work-time control and variability of working time on recovery from fatigue, sleep quality, and work-life balance, and on the occurrence of self-reported "near misses" at work. High work-time control and variability had favourable influences on health and work-life balance [43].

One study has shown that objective sleep efficiency based on actigraphy recordings was unrelated to variations in both psychosocial work characteristics and negative affective responses, while self-recorded poor sleep was more prevalent among those overcommitted to work or with lower social support at work [44]. Another study showed that a workweek with a high workload and much stress increases sleepiness, and impairs sleep, and affects the pattern of diurnal cortisol secretion with a more flattened pattern probably due to increased evening levels during the stressing week [45]. Day-to-day variations in self-reported fatigue by sleep-diaries is related to poor sleep quality, reduced sleep duration the previous night (measured by actigraphy recordings), higher stress level and to the occurrence of a cold or fever during the same day [46].

IRREGULAR WORK AND SLEEP QUANTITY

While most adults need between 7 and 9 h of sleep per day, preferably during a single major sleep period at night, this may be difficult to obtain at sea — in particular with work in shifts. Fatigue related to shift work has been studied in seafarers, and clear differences between daytime workers and shift workers, and between various watch systems have been observed. In a case-control study of rotating shift workers and daytime workers the sleep profile was similar in the two groups, but insomnia was found to be closely related to sleep time, anxiety, depression, fatigue, and impaired quality of life [47]. Alertness was found to be lower in rotating watch systems than in a steady watch system [48].

Shift work causes difficulties getting to sleep, shortened sleep, and sleepiness during working days that continues into successive days off. This can only be partly improved by manipulating shift patterns. There is no clear indication that chronic sleep problems result from long-term shift work [49] although this is suggested by retrospective studies [50].

Shift work and long working hours contributes to sleep debt [51]. When shift work includes night work, it has pronounced negative effects on sleep, subjective and physiological sleepiness, performance, and accident risk, as well as on secondary health outcomes such as cardiovascular diseases. The reason for that is the conflict between the day-oriented circadian physiology and the requirement for work and sleep at the "wrong" biological time of day. Other factors that negatively impact work shift sleepiness and the associated accident risk include long duration work-shifts in excess of 12 h and individual vulnerability for phase intolerance. This may lead to a shift work related disorder in workers with the greatest impairment of sleepiness and performance during the biological night and insomnia during the biological day [52].

Shift work-related insomnia differs between various work schemes with evening shift insomnia more prevalent in 2-shift rotation than in 3-shift rotation schedule (29.8% and 19.8%, respectively). Night shift insomnia was higher among 3-shift rotation workers compared with permanent night workers (67.7% and 41.7%, respectively). Rest-day insomnia was more prevalent among permanent night workers compared with 2- and 3-shift rotations (11.4% compared with 4.2% and 3.6%, respectively) [53].

Changing from a forward rotating to a backward rotating shift system is likely to increase sleep difficulties between successive afternoon shifts but to decrease social disruption [54]. Fatigue is more pronounced in 2-watch systems (e.g., 6 on/6 off) than in 3-watch systems (e.g., 4 on/8 off) [15, 17] and most obvious between 4:00 and 6:00 h when the biological pressure to sleep is at its highest [15].

Eriksen et al. [16] have demonstrated that, within a 6 on//6 off system, the levels of sleepiness are highest during the night shift from midnight to 6 a.m. and rises towards the end of the shift. The 6/6-watch system (12 daily work hours) is related to higher risk of severe sleepiness for marine officers during the early morning hours compared to the 4/8-watch system with 8 daily work hours. The officers reported shorter sleep duration, more frequent nodding-off on duty and excessive sleepiness. 17.6% had fallen on sleep at least once while on duty during their career [15].

These findings were confirmed in the HORIZON project, in which 3 linked marine simulators were applied for creating a sustainable and realistic voyage experience. Bridge and engine crew was studied on 4 on/8 off and 6 on//6 off-watch systems. Sleep and sleepiness were objectively assessed by polysomnographic recordings [18, 55, 56]. There was a high frequency of severe sleepiness, indicated by several officers actually falling asleep whilst on watch. The 6 on/6 off watch regime appeared to be more sleepiness inducing than the 4 on/8 off, with more incidents of seafarers falling asleep. The onset of sleepiness on 6 on/6 off was apparent over a shorter timeframe than predicted from previous research. Marine watch keepers were shown to be most sleepy during night watches and showed signs of sleepiness in the afternoon. Sleepiness increased gradually during the work periods as the week progressed. This study has also demonstrated a profound impact of sleep disturbances during rest periods, and that the actual amount of sleep obtained by watch keepers when off watch was less than anticipated. The total amount of sleep that watch keepers managed to obtain on 6 on/6 off was less than normally required for full rest. Watch keepers' sleep time averaged 6.5 h in total, split up into two sessions: the main one during the "night" time, followed by a "nap" during the other rest period [57]. The subjective as well as objective peaks of sleepiness during night and early morning watches coincided with the time frame in which relatively many maritime accidents occur. Overtime work was shown to have a strong impact on sleepiness. A striking number of participants fell asleep during work after a short period of mild overtime work [18].

Similar findings were reported in a study by Lützhöft et al. [17], who also reported shorter sleep periods within a 6/6 system, where sleep was more often split into 2 episodes. The level of sleepiness was higher on the 00:00–06:00 and 06:00–12:00 watch with increasing sleepiness towards the end of the watch. The sleep duration differed in between the various watches with longer sleep during the 06:00–12:00 and 18:00–24:00 off-duty periods [16].

Whether sleep was fragmented into 2/3 episodes on an oceanographic vessel or 5/6 episodes on a fishing vessel, the 24 h circadian alertness rhythm assessed by Visual Analogue Scales and actigraphs was preserved in both instances with seafarers having a circadian alertness dip during night time and a pronounced afternoon dip. The sleep fragmentation should be viewed not only as an occupational phenomenon but also with social factors such as meal times playing a role [58].

SLEEP QUALITY

Not all sleep is of the same quality and contains the same recuperative benefits. The highest sleep quality is obtained at night while sleeping at other times is prone to be more disrupted and shorter, and therefore of lower quality. Good recuperation requires about 6 h of uninterrupted sleep for a person who normally sleeps 8 h.

Objective measures of sleep continuity are closely related to perceived sleep quality in the sense that sleep quality is essentially comparable to sleep continuity [59]. Disturbed sleep seems to be a stronger predictor for fatigue than other well-established risk factors for fatigue [13]. This is in accordance with the observation that subjective calmness of sleep and ease of falling asleep improves sleep quality and that the duration of wakefulness prior to sleep and the timing of sleep determines the subjective experience of sleep quality [60]. Difficulties awakening after sleep is shown to be related to high work demands, low social support, being male, low age and smoking [30]. Disturbed sleep is related to female gender, age above 49 years, present illness, hectic work, physically strenuous work, and shift work [26].

PHYSICAL RISK FACTORS

Exposure to a ship's engine noise at 65 dB(A) can have an adverse effect on sleep [61], but this seems to be more a subjective effect, e.g. relating to sleep quality, which was not apparent with actigraphy [62]. Sleep tended to be often interrupted through noise and ships' movement in several studies [7, 25]. Related to a moving environment, motion sickness — experienced by most seafarers — is a major cause of fatigue [63]. There is, however, little evidence about the severity of ships' motions that degrade physical and mental performance [64]. It has been demonstrated that crews experience more constraints in terms of motion sickness and fatigue on days when vessel motions increased, with certain activities and responses being particularly influenced by vessel motions [65].

INDIVIDUAL RISK FACTORS

Large individual differences in the effects of shift duty scheduling were shown in a study of naval day workers and night workers, so that the strategies addressing fatigue need to take into account that different individuals may be more suited to different shifts [66]. Out of several individual factors with a detrimental effect on circadian rhythms, age is an issue because there is a tendency towards an ageing workforce in the maritime industry. Ageing decreases the speed of circadian adaptation to night work and has a major impact on sleep quality and chronic disease risk factors [67]. Sleep disorders are also more prevalent in older workers. Practical countermeasures to improve the conditions of older workers should aim to fit work demands flexibly to ageing workers with different levels of work ability, health and social needs [68]. In a study of naval seafarers, older personnel did not suffer from more work-related fatigue than younger personnel, but work-related fatigue was found to accumulate over time with continuous exposure to work demands on board [69].

While older shift-workers tend to report more subjective sleepiness that decreases their work performance during morning and night shifts [14], a systematic review of tolerance to shift work for older people reached conflicting results and concludes that there is only limited evidence for older people to be less tolerant. Still it is argued that age-specific aspects should be considered in shift work planning [70]. However, subjective sleep quality is becoming inferior and difficulties awakening and feelings of not being well rested after sleep increase with age [26, 30]. In contrast, fatigue appears to be more prominent for younger subjects below the age of 49 years [26].

ACUTE RESPONSES

ACUTE SAFETY EFFECTS

Within occupational medicine and traffic medicine, the concerns relating to safety issues are the main focus of the interest in fatigue.

Transport workers are prone to become sleepy and eventually to fall asleep during work [15, 57]. In the driving sector, sleepy drivers have been estimated to be involved in at least 15–20% of accidents [71]. It is not easy to clearly retrospectively relate sleepiness to maritime accidents, but in a study of 279 maritime incidents the United States Coast Guard estimated that fatigue contributed to 16% of the critical vessel casualties and 33% of the personal injuries [20]. In a study of 1647 collisions, groundings, contacts and near collisions the British Marine Investigation Branch estimated that a third of all groundings involved a fatigued officer alone at the bridge at night, that two-thirds of vessels involved in collisions were not keeping a proper lookout, and that a third of all accidents that occurred at night involved a sole watch-keeper on the bridge. The main concerns from this study was fatigue, lookout, safe manning and the role of the master [72].

While reduced sleep and sleepiness in itself is an explanatory factor of accidents, the context of reduced sleep is also important since suboptimal work schedules and lifestyle, and sleep pathology are equally important factors [73]. A review of 20 studies of safety in shipping across fatigue, stress, health, situation awareness, teamwork, decision-making, communication, automation, and safety culture concluded that modifications of human factor issues should be a focus for interventions [74]. The risk of accidents is higher at night (and to a lesser degree afternoon) compared to the morning. It increases over a series of shifts and as shifts exceed 8 h [75].

ACUTE HEALTH RELATED EFFECTS

Disturbed sleep is the most common acute health-related effect of shift work, in particular with regard to difficulty getting to sleep, shortened sleep and sleepiness during working hours that continues into successive days off [49]. Falling asleep during wake time is another consequence of fatigue [15, 18, 30]. Since shift work and the associated fatigue impairs cognition it can potentially lead to misjudgements and accidents [76].

CHRONIC RESPONSES

Chronic fatigue may follow repeated exposures to acute fatigue or represent a persistent failure of sufficient rest and recuperation to overcome fatigue. The pathways from fatigue to chronic disease are complex and not fully understood but involved mechanisms include metabolic, autonomous, and immunological pathways.

Chronic sleep debt leads to chronic circadian disruption of the immune response [77] and increases the risk of developing cardiovascular diseases [78]. Autonomic changes relating to a reduced parasympathetic modulation may result from lifetime shift work [79, 80]. Disruption of the circadian regulation of the human transcriptome is another implicated mechanism behind fatigue that is related to mistimed sleep. Delaying sleep by 4 h for 3 consecutive days has led to a 6-fold reduction of the human blood transcriptome while the centrally mediated circadian rhythm of melatonin remains unaffected [81]. Fatigue from night and shift work alters the hormonal and sleepiness cycles and the lipid and glucose metabolism [82]. Despite signs indicating such possible disease mechanisms, however, compelling evidence remains to arise [83].

CHRONIC PSYCHOSOCIAL EFFECTS AND SLEEP DISORDERS

Experimental studies have demonstrated that chronic sleep loss cumulatively increases the rate of deterioration in performance across wakefulness, in particular during the circadian "night" [84]. Fatigue favours sleeping disorders such as insomnia, and delayed or advanced sleep-phase disorders and interferes with behaviour and social life [68, 82].

Insomnia, the inability to fall asleep and/or to stay asleep as long as desired, is the most common sleep disorder related to irregular work hours such as shift-work. Sleep apnoea//hypopnoea is a common sleep disorder among overweight men who snore. The affected subject may not be aware of the condition, which causes sleepiness and fatigue when awake. While this condition is not caused by fatigue per se, it is related to fatigue in the sense that fatigue related to sleep deprivation contributes to a preference for high caloric food that may result in overweight and metabolic changes. Delayed or advanced sleep-phase symptoms occur when the circadian rhythm is out of phase with the environment. Delayed sleep-phase syndrome causes difficulties to sleep at night and is mainly affecting younger persons while advanced sleep-phase syndrome causes trouble to stay awake in the evening and waking up early in the morning.

CHRONIC SOMATIC HEALTH EFFECTS

In addition to impaired cognition [76], chronic exposure to shift work has been demonstrated to cause a number of other significant health implications [85]. Fatigue from night and shift work may affect the gastrointestinal and cardiovascular functions through altered hormonal and sleepiness cycles [86].

Peptic ulcer and symptoms related to irritable bowel syndrome are increased in shift-workers and there is no doubt that shift work is a significant risk factor for coronary heart disease [68]. The autonomous consequences of lifetime shift work lead to increased blood pressure [79, 80]. The intake by shift workers of more pro-inflammatory diets compared to day workers [87] contribute to their cardiovascular risk, which may also be increased through additional interrelated psychosocial (difficulties in controlling work hours, decreased work-life balance, poor recovery following work), behavioural (weight gain and smoking) and physiological mechanisms (activation of the autonomic nervous system, inflammation, altered lipid and glucose metabolism with related changes in risks for atherosclerosis, metabolic syndrome and type 2 diabetes). In spite of signs indicating such possible disease mechanisms, however, compelling evidence remains to be elucidated [83]. However, an increased overall risk profile of cardiovascular disease mortality has been demonstrated with incomplete recovery from work in terms of having work free weekends [88]. This aspect may be highly relevant for seafarers subjected to extended periods (months) at sea.

Many studies have linked short sleep duration to obesity through pathways of increased high caloric food intake and reduced energy expenditure during daytime, which is related to sedentary behaviour. Fatigue, adverse sleep patterns and shift work are known risk factors for obesity, and lead to high levels of triglycerides and low high-density lipoprotein cholesterol. These metabolic changes indicate an increased risk of metabolic syndrome [1, 89, 90], which is more prevalent among former shift workers than in workers who have never worked in shifts [91], and among seafarers than in the general population [92]. Short sleep duration is correlated to an increased risk of adult overweight/obesity and some studies claim this to be related to a reduced circulating leptin level relative to what is predicted by fat mass [93], whereas others have found increased circulating leptin levels after a period of short sleep [36]. It should be noted, however, that experimental studies are far from consistent where it concerns the metabolic consequences of short sleep duration [94–96]. Shift work has been found to be associated with unfavourable dietary habits and consequently to overweight and related chronic diseases such as coronary heart disease, metabolic syndrome and type 2 diabetes [97]. Night shift work, in particular for workers of older ages, increases obesity [98], calorie intake, and smoking, and causes shorter sleep duration [67]. A meta-analysis has recently demonstrated that shift work is associated to an increased risk of diabetes mellitus, in particular among men with rotating shifts [99].

Shift work has been shown to be associated with a higher risk of common infections [100], possibly mediated through a lack of oxidative capacity.

The joint additional effect of adverse lifestyle factors such as smoking, sedentary lifestyle, and obesity, which is also prevalent among seafarers, is regarded as multiplicative [68]. Individuals whose working hours exceed standard recommendations are more likely to increase their alcohol use to levels that pose a health risk [101].

The International Agency for Research on Cancer has classified shift work as a probable human carcinogen but research on this issue is complex [102]. For males prostate carcinoma has been particular implicated [103].

Along with other psychosocial stressors, fatigue is regarded as associated with mental health risks [38]. Psychiatric conditions such as major depression are increased among shift-workers and their prevalence increases with the length of exposure and age [68].

FATIGUE MITIGATION

Countermeasures for fatigue in transportation, including seafaring, has been recently reviewed in a comprehensive Swedish report [104]. Reducing seafarers' fatigue requires external and company regulation and control as well as individual preventive intervention and human resilience. Fatigue mitigating factors include alertness management strategies of which proper work-rest scheduling and adequate sleep hygiene are of primary importance [105]. Whereas countermeasures (scheduling, education, naps, caffeine etc.) — preferably in combination — may ameliorate the negative impact of shift work on night time sleepiness and day time insomnia, there seems at present to be no way of eliminating most negative effects of shift work on human physiology and cognition [52]. Recent advice on best practices have been published by SeaHealth — the occupational health service for the Danish merchant fleet [106].

INTERNATIONAL REGULATION

The International Labour Organisation (ILO) Convention 180 on Seafarers' Hours of Work and Manning of Ships that came into force in 2002 dictate a maximum amount of work of 14 h in any 24-h period and up to 72 h in any 7-day period. The minimum hours of rest should be not less than 10 h in any 24-h period and 77 h in any 7-day period. The hours of rest may be divided into no more than 2 periods, one of which must be at least 6 h in length and the interval between consecutive periods must not exceed 14 h.

Other ILO Conventions 92, 133, 140, 141, and 147 introduce additional minimal habitability requirements on board ships such as noise control and air conditioning.

IMO instruments concerning fatigue include the International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW) Code, which requires alertness to factors that can contribute to fatigue including excessive or unreasonable overall working hours and to the frequency and length of leave periods as material factors in preventing fatigue to build up over a period of time. The limits of hours at work and hours at rest contained in the Maritime Labour Convention 2006 are similar to those in ILO 180.

The International Safety Management (ISM) Code states that if fatigue, excessive hours of work, or lack of adequate rest are or should be apparent, the master and the company management should intervene to immediately remedy the problem. The Code reiterates the important position held by the master of a ship but also states that the company will not absolve itself from responsibility by delegating the responsibility for managing safety on board to the master. The company is also responsible for ensuring their masters' monitoring and managing of their own hours of work//rest so that they do not suffer from fatigue. The company must ensure that master, officers and crew are properly qualified, experienced, trained and familiarised and sufficient in number. The safe manning certificate determines the required manning to run a particular ship safely at a particular time. The Code requires the company to prepare plans and instructions, including checklists for 'key shipboard operations', which will depend on the type of ship and its operational requirements (navigation and bridge management, cargo operations and management, etc.). The management of personnel and their hours of work and rest should ensure that the various tasks can be performed safely and that fatigue is prevented. Seafarers who are too tired for acting safely should not perform operational tasks, and procedures should prevent this from happening. While the ISM Code cannot achieve immediate perfection it should initiate a cycle of continuous improvement and proactive steps. It also allows a reactive approach by learning from experienced system failures, including previous corrective actions. Any situation on board where a seafarer is not achieving the minimum hours of rest or works excessive hours and is possibly suffering from fatigue must be recorded and reported.

COLLECTIVE FATIGUE MITIGATION MANAGEMENT

Fatigue should be regarded as a serious health and safety issue and therefore securing sufficient quality sleep is the first and most important way of fatigue mitigation. This will promote recovery while insufficient rest and suboptimal sleep will exacerbate fatigue, which may eventually accumulate over time [77]. Keeping fixed watch schedules for mitigating fatigue has been proposed [48], but the feasibility in a broader context remains to be shown.

Houtman et al. [107] emphasized proper implementation of the ISM Code as essential to reduce fatigue and consequently to focus upon company-based strategic solutions. This requires a more robust and realistic approach to regulation and manning. While vessels may already operate with more crew than demanded by their flag state, the operational mode must also be taken into account [108]. The crew-size may be adequate for open sailing but insufficient for maintenance, recovery, port turn-arounds, or with specific security requirements. A level of redundancy requires manning specifications to be universal for all vessels to prevent economic advantage accruing to companies who operate with bare minimums. A comparison in between a ship with a 24-man crew and a ship with an 18-man crew demonstrated that the latter had longer working hours, a higher level of catecholamine excretion and higher stress levels [109].

To cope with fatigue, learning experiences should be drawn from different maritime sectors as well as from other transport sectors that are prone to fatigue, notably the aviation industry, which has dealt significantly with this issue [110]. Learning from best practices requires the collaborate efforts of all stakeholders such as the work force, regulators and academics.

Under-recording of working hours to comply with the legislation is contra-active in relation to fatigue mitigation. It has been shown that seafarers who under-reported at least occasionally their working hours were significantly more fatigued and less healthy than non under-recording seafarers [8, 9].

To promote good quality sleep, the cabins should be quite, dark and cool, i.e. protected from noise and vibration to the extent possible, with an option for shielding off daylight, and with efficient air conditioning facilities. Single cabins should be offered for undisturbed sleep.

INDIVIDUAL FATIGUE MITIGATION MANAGEMENT

Certain circumstances on board cannot be changed, e.g. the weather, and the waves, and naval architects at the best are only likely to modify/reduce the ships' motion. Taking into account that legislation and compliance cannot solve all issues relating to fatigue, collective mitigation cannot stand alone. The seafarer's own behaviour is also important.

The seafarer would benefit from taking actions such as calming down and avoiding caffeine and alcohol prior to sleep. It is important to spend as much time as possible in daylight, and to be active (physically and mentally) during the day but not too close to bedtime. The seafarer should attempt to follow his own circadian rhythm by sleeping and waking early if a morning person and sleeping and waking late if an evening person.

The cabin should be prepared for sleep by shielding out light and to secure coolness (below 20°C). Phone and doorbell should be switched off. Relaxing, reading or listening to soothing music before sleeping can help getting ready for sleep. Nicotine and alcohol should be avoided 2 h before sleep, and caffeine 6 h before sleep. Heavy exercise should also be avoided 2 h before going to bed. If hungry, only light food is recommended.

There are several additional countermeasures to ameliorate the negative impact of irregular work on night-time-sleepiness while working and daytime insomnia when there is a need of sleeping during the day. Even when these measures are applied (probably best in combination), however, there seems at present to be no way to eliminate most of the negative effects of shift work on human physiology and cognition [52].

Blue light exposure [111], caffeine [112, 113] and naps [112–114] have all been demonstrated to mitigate fatigue. Naps should be kept short (15–40 min) to avoid waking up from deep sleep. A nap should be scheduled to the last 2 h before a night shift and end 1 h before starting work. Lifestyle issues such as regular exercises and healthy diet habits promote the general health, and at the same time affect positively sleep and reduce fatigue. Worksite healthy sleep programs have shown the effectiveness of tailored interventions [115]. As a part of the MARTHA project [116], which currently studies international seafarers' perceptions regarding perceived causal factors and sleep patterns, the Stress Research Institute at University of Stockholm has recently released "Fatigue — a self-health guide" to be used for a trial on fatigue mitigation on board.

A recent Cochrane report concluded that the effect of melatonin had only a limited effect on sleep duration during daytime after night shifts but no effect on sleep quality. There is insufficient knowledge for an effect of hypnotics on sleep length [117]. In spite of melatonin and hypnotics being available over the counter in many countries, medicaments addressing sleep problems are not recommended by the authors. Their side effects may well be worse than the problem that one tries to solve by taking them.

FATIGUE PREDICTION

Various models for fatigue prediction have been recently reviewed and the current generation of such models is regarded as an appropriate element in a fatigue risk management system to be applied in field settings by organisations and regulators. It is, however, emphasized that individual and task variables are not included in the current models [118] and the user interphase has limited user-friendliness. The HORIZON project [57] has pointed to ways of mitigating fatigue [119] and developed a software tool for maritime use for fatigue prediction [120]. As a part of a Fatigue Risk Management System this tool may eventually allow the shipping industry to approach new goal-based practices.

REFERENCES

1. Kaltsas G, Vgontzas A, Chrousos G. Fatigue, endocrinopathies, and metabolic disorders. PMR 2010; 2: 393–398.
2. IMO. Guidelines on Fatigue. International Maritime Organization 2002.
3. Smith AP, Allen PH, Wadsworth EM ed. A comparative approach to seafarers' fatigue2007; Proceedings of the International Symposium on Maritime Safety, Science and Environmental Protection, Athens.
4. Ohayon MM, Smolensky MH, Roth T. Consequences of shiftworking on sleep duration, sleepiness, and sleep attacks. Chronobiol Int 2010; 27: 575–589.
5. Smith AP, Lane T, Bloor M, Allen P, Burke A, Ellis N. Fatigue offshore: Phase 2. The short sea and coastal shipping industry. Seafarers International Research Centre/Centre for Occupational and Health Psychology, Cardiff University, Cardiff 2003.
6. Smith AP, Lane T, Bloor M. Fatigue offshore: A comparison of offshore oil support shipping and the offshore oil industry. Seafarers International research Centre/Centre for Occupational and health Psychology, Cardiff University, Cardiff 2001.
7. Wadsworth EJ, Allen PH, Wellens BT, McNamara RL, Smith AP. Patterns of fatigue among seafarers during a tour of duty. Am J Ind Med 2006; 49: 836–844.
8. Allen P, Wadsworth E, Smith A. Seafarers' fatigue: a review of the recent literature. Int Marit Health 2008; 59: 81–92.
9. Allen P, Wadsworth E, Smith A. The relationship between recorded hours of work and fatigue in seafarers In: Bust PD ed. Contemporary Ergonomics. Taylor and Francis, London 2006; 546–548.
10. Kaida K, Takahashi M, Akerstedt T et al. Validation of the Karolinska sleepiness scale against performance and EEG variables. Clin Neurophysiol 2006; 117: 1574–1581.
11. van den Berg J, Neely G, Nilsson L, Knutsson A, Landstrom U. Electroencephalography and subjective ratings of sleep deprivation. Sleep Med 2005; 6: 231–240.
12. Akerstedt T, Kecklund G, Axelsson J. Effects of context on sleepiness self-ratings during repeated partial sleep deprivation. Chronobiol Int 2008; 25: 271–278.
13. Akerstedt T, Knutsson A, Westerholm P, Theorell T, Alfredsson L, Kecklund G. Mental fatigue, work and sleep. J Psychosom Res 2004; 57: 427–433.
14. Bonnefond A, Harma M, Hakola T, Sallinen M, Kandolin I, Virkkala J. Interaction of age with shift-related sleep-wakefulness, sleepiness, performance, and social life. Exp Aging Res 2006; 32: 185–208.
15. Harma M, Partinen M, Repo R, Sorsa M, Siivonen P. Effects of 6/6 and 4/8 watch systems on sleepiness among bridge officers. Chronobiol Int 2008; 25: 413–423.
16. Eriksen CA, Gillberg M, Vestergren P. Sleepiness and sleep in a simulated "six hours on/six hours off" sea watch system. Chronobiol Int 2006; 23: 1193–1202.
17. Lutzhoft M, Dahlgren A, Kircher A, Thorslund B, Gillberg M. Fatigue at sea in Swedish shipping: a field study. Am J Ind Med 2010; 53: 733–740.
18. van Leeuwen WM, Kircher A, Dahlgren A et al. Sleep, sleepiness, and neurobehavioral performance while on watch in a simulated 4 hours on/8 hours off maritime watch system. Chronobiol Int 2013; 30: 1108–1115.
19. Kaida K, T AK, Kecklund G, Nilsson JP, Axelsson J. The effects of asking for verbal ratings of sleepiness on sleepiness and its masking effects on performance. Clin Neurophysiol 2007; 118: 1324–1331.

20. Board NTS. Evaluation of US Department of Transportation. Efforts in the 1990s to address operator fatigue. Washington DC 1999.
21. Dittner AJ, Wessely SC, Brown RG. The assessment of fatigue: a practical guide for clinicians and researchers. J Psychosom Res 2004; 56: 157–170.
22. Smets EM, Garssen B, Bonke B, De Haes JC. The Multidimensional Fatigue Inventory (MFI) psychometric qualities of an instrument to assess fatigue. J Psychosom Res 1995; 39: 315–325.
23. Lin JM, Brimmer DJ, Maloney EM, Nyarko E, Belue R, Reeves WC. Further validation of the Multidimensional Fatigue Inventory in a US adult population sample. Population Health Metrics 2009; 7: 18.
24. Wadsworth EJ, Allen PH, McNamara RL, Smith AP. Fatigue and health in a seafaring population. Occup Med (Lond) 2008; 58: 198–204.
25. Smith A, Allen P, Wadsworth E. Seafarers fatigue: The Cardiff Research Programme. Centre for Occupational and Health Psychology, Cardiff 2006.
26. Akerstedt T, Fredlund P, Gillberg M, Jansson B. Work load and work hours in relation to disturbed sleep and fatigue in a large representative sample. J Psychosom Res 2002; 53: 585–588.
27. A Hovdanum AS, Jensen OC, Petursdottir G, Holmen IM. A review of fatigue in fishermen: a complicated and underprioritised area of research. Int Marit Health 2014; 65: 166–172.
28. Gander P, van den Berg M, Signal L. Sleep and sleepiness of fishermen on rotating schedules. Chronobiol Int 2008; 25: 389–398.
29. Allen P, Wellens BT, Smith A. Fatigue in British fishermen. Int Marit Health 2010; 61: 154.
30. Akerstedt T, Knutsson A, Westerholm P, Theorell T, Alfredsson L, Kecklund G. Sleep disturbances, work stress and work hours: a cross-sectional study. J Psychosom Res 2002; 53: 741–748.
31. Cappuccio FP, Cooper D, D'Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. Eur Heart J 2011; 32: 1484–1492.
32. Xi B, He D, Zhang M, Xue J, Zhou D. Short sleep duration predicts risk of metabolic syndrome: a systematic review and meta-analysis. Sleep Med Rev 2014; 18: 293–297.
33. Wang Q, Xi B, Liu M, Zhang Y, Fu M. Short sleep duration is associated with hypertension risk among adults: a systematic review and meta-analysis. Hypertens Res 2012; 35: 1012–1018.
34. Ferrie JE, Kumari M, Salo P, Singh-Manoux A, Kivimaki M. Sleep epidemiology–a rapidly growing field. Int J Epidemiol 2011; 40: 1431–1437.
35. Tobaldini E, Pecis M, Montano N. Effects of acute and chronic sleep deprivation on cardiovascular regulation. Archives Italiennes de Biologie 2014; 152: 103–110.
36. van Leeuwen WM, Hublin C, Sallinen M, Harma M, Hirvonen A, Porkka-Heiskanen T. Prolonged sleep restriction affects glucose metabolism in healthy young men. Int J Endocrinol 2010; 2010: 108641.
37. Harma M. Psychosocial work characteristics and sleep: a well-known but poorly understood association. Scand J Work Environ Health 2013; 39: 531–533.
38. Carotenuto A, Molino I, Fasanaro AM, Amenta F. Psychological stress in seafarers: a review. Int Marit Health 2012; 63: 188–194.
39. Akerstedt T, Kecklund G, Axelsson J. Impaired sleep after bedtime stress and worries. Biol Psychol 2007; 76: 170–173.
40. Akerstedt T. Psychosocial stress and impaired sleep. Scand J Work Environ Health 2006; 32: 493–501.
41. van Laethem M, Beckers DG, Kompier MA, Dijksterhuis A, Geurts SA. Psychosocial work characteristics and sleep quality: a systematic review of longitudinal and intervention research. Scand J Work Environ Health 2013; 39: 535–549.
42. de Lange AH, Kompier MA, Taris TW et al. A hard day's night: a longitudinal study on the relationships among job demands and job control, sleep quality and fatigue. J Sleep Res 2009;18: 374–383.
43. Kubo T, Takahashi M, Togo F et al. Effects on employees of controlling working hours and working schedules. Occup Med (Lond) 2013; 63: 148–151.
44. Jackowska M, Dockray S, Hendrickx H, Steptoe A. Psychosocial factors and sleep efficiency: discrepancies between subjective and objective evaluations of sleep. Psychosom Med 2011; 73: 810–816.
45. Dahlgren A, Kecklund G, Akerstedt T. Different levels of work-related stress and the effects on sleep, fatigue and cortisol. Scand J Work Environ Health 2005; 31: 277–285.
46. Akerstedt T, Axelsson J, Lekander M, Orsini N, Kecklund G. Do sleep, stress, and illness explain daily variations in fatigue? A prospective study. J Psychosom Res 2014; 76: 280–285.
47. Vallieres A, Azaiez A, Moreau V, LeBlanc M, Morin CM. Insomnia in shift work. Sleep Med 2014; 15: 1440–1448.
48. Arulanandam S, Tsing CG. Comparison of alertness levels in ship crew. An experiment on rotating versus fixed watch schedules. Int Marit Health 2009; 60: 6–9.
49. Akerstedt T. Shift work and disturbed sleep/wakefulness. Occup Med (Lond) 2003; 53: 89–94.
50. Dumont M, Montplaisir J, Infante-Rivard C. Sleep quality of former night-shift workers. Int J Occup Environ Health 1997; 3 (suppl. 2): S10–S14.
51. Bayon V, Leger D, Gomez-Merino D, Vecchierini MF, Chennaoui M. Sleep debt and obesity. Ann Med 2014; 46: 264–272.
52. Akerstedt T, Wright KP, Jr. Sleep loss and fatigue in shift work and shift work disorder. Sleep Med Clin 2009;4: 257–271.
53. Flo E, Pallesen S, Akerstedt T et al. Shift-related sleep problems vary according to work schedule. Occup Environ Med 2013; 70: 238–245.
54. Barton J, Folkard S, Smith L, Poole CJ. Effects on health of a change from a delaying to an advancing shift system. Occup Environ Med 1994; 51: 749–755.
55. Maurier P, Barnett M, Peckan C, Gatfield D, Corrignan P, Clarke G ed. Fatigue and performance in bridge and engine control room watchkeeping on a 6on/6off watch regime. International Conference on Human Factors in Ship Design, London 2011.
56. Barnett M, Peckan C, Gatfield D ed. The use of linked simulators in project "HORIZON": Research into seafarer fatigue. MARSIM, Singapore 2012.
57. Project HORIZON — Final Report Findings Southampton [3. March 2015]. Available from: http://www.warsashacademy.co.uk/about/resources/final-horizon-report-final-as-printed.pdf.
58. Tirilly G. The impact of fragmented sleep at sea on sleep, alertness and safety of seafarers. Medicina Maritima 2004; 4: 96–105.
59. Akerstedt T, Hume K, Minors D, Waterhouse J. The meaning of good sleep: a longitudinal study of polysomnography and subjective sleep quality. J Sleep Res 1994; 3: 152–158.
60. Akerstedt T, Hume K, Minors D, Waterhouse J. Good sleep — its timing and physiological sleep characteristics. J Sleep Res 1997; 6: 221–229.
61. Tamura Y, Kawada T, Sasazawa Y. Effect on ship's noise on sleep. J Sound Vibration 1997; 205: 417–425.
62. Tamura Y, Horiyasu T, Sano Y, Chonan K, Kawada T, Sasazawa Y. Habituation of sleep to a ship's noise as determined by actigraphy and a sleep questionnaire. J Sound Vibration 2002; 250: 107–113.
63. Wertheim AH. Working in a moving environment. Ergonomics 1998; 41: 1845–1858.

64. Pisula PJ, Lewis CH, Bridger RS. Vessel motion thresholds for maintaining physical and cognitive performance: a study of naval personnel at sea. Ergonomics 2012; 55: 636–649.
65. Haward BM, Lewis CH, Griffin MJ. Motions and crew responses on an offshore oil production and storage vessel. Appl Ergon 2009; 40: 904–914.
66. Goh VH. Circadian disturbances after night-shift work onboard a naval ship. Military Medicine 2000; 165: 101–105.
67. Ramin C, Devore EE, Wang W, Pierre-Paul J, Wegrzyn LR, Schernhammer ES. Night shift work at specific age ranges and chronic disease risk factors. Occup Environ Med 2015; 72: 100–107.
68. Harma MI, Ilmarinen JE. Towards the 24-hour society — new approaches for aging shift workers? Scand J Work Environ Health 1999; 25: 610–615.
69. Bridger RS, Brasher K, Dew A. Work demands and need for recovery from work in ageing seafarers. Ergonomics 2010; 53: 1006–1015.
70. Blok MM, de Looze MP. What is the evidence for less shift work tolerance in older workers? Ergonomics 2011; 54: 221–232.
71. Horne JA, Reyner LA. Counteracting driver sleepiness: effects of napping, caffeine, and placebo. Psychophysiology 1996; 33: 306–309.
72. Bridge Watchkeeping Safety Study. Southampton: MAIB Marine Accident Investigation Branch, 2004 July 2004. Report No.: Safety Study 1.
73. Akerstedt T, Philip P, Capelli A, Kecklund G. Sleep loss and accidents — work hours, life style, and sleep pathology. Prog Brain Res 2011; 190: 169–188.
74. Hetherington C, Flin R, Mearns K. Safety in shipping: the human element. J Safety Res 2006; 37: 401–411.
75. Folkard S, Lombardi DA, Tucker PT. Shiftwork: safety, sleepiness and sleep. Industrial Health 2005; 43: 20–23.
76. Marquie JC, Tucker P, Folkard S, Gentil C, Ansiau D. Chronic effects of shift work on cognition: findings from the VISAT longitudinal study. Occup Environ Med 2015; 72: 258–264.
77. van Mark A, Weiler SW, Schroder M, Otto A, Jauch-Chara K, Groneberg DA, et al. The impact of shift work induced chronic circadian disruption on IL-6 and TNF-alpha immune responses. J Occup Med Toxicol 2010; 5: 18.
78. van Leeuwen WM, Lehto M, Karisola P et al. Sleep restriction increases the risk of developing cardiovascular diseases by augmenting proinflammatory responses through IL-17 and CRP. PLoS One 2009; 4: e4589.
79. Bernardes Souza B, Mussi Monteze N, Pereira de Oliveira FL et al. Lifetime shift work exposure: association with anthropometry, body composition, blood pressure, glucose and heart rate variability. Occup Environ Med 2015; 72: 208–215.
80. Kubo T, Fujino Y, Nakamura T et al. An industry-based cohort study of the association between weight gain and hypertension risk among rotating shift workers. J Occup Environ Med 2013; 55: 1041–1045.
81. Archer SN, Laing EE, Moller-Levet CS et al. Mistimed sleep disrupts circadian regulation of the human transcriptome. Proc Natl Acad Sci USA 2014; 111: E682–E691.
82. Garbarino S, Beelke M, Costa G et al. Brain function and effects of shift work: implications for clinical neuropharmacology. Neuropsychobiology 2002; 45: 50–56.
83. Puttonen S, Harma M, Hublin C. Shift work and cardiovascular disease — pathways from circadian stress to morbidity. Scand J Work Environ Health 2010; 36: 96–108.
84. Cohen DA, Wang W, Wyatt JK et al. Uncovering residual effects of chronic sleep loss on human performance. Sci Transl Med 2010; 2: 14ra3.
85. van Mark A, Spallek M, Kessel R, Brinkmann E. Shift work and pathological conditions. J Occup Med Toxicol 2006; 1: 25.
86. Knutsson A. Health disorders of shift workers. Occup Med (Lond) 2003; 53: 103–108.
87. Wirth MD, Burch J, Shivappa N et al. Association of a dietary inflammatory index with inflammatory indices and metabolic syndrome among police officers. J Occup Environ Med 2014; 56: 986–989.
88. Kivimaki M, Leino-Arjas P, Kaila-Kangas L et al. Is incomplete recovery from work a risk marker of cardiovascular death? Prospective evidence from industrial employees. Psychosom Med 2006; 68: 402–407.
89. Karlsson B, Knutsson A, Lindahl B. Is there an association between shift work and having a metabolic syndrome? Results from a population based study of 27,485 people. Occup Environ Med 2001; 58: 747–752.
90. Shift work and sleep: optimizing health, safety, and performance. J Occup Environ Med 2011;53 (5 suppl.): S1–S10; quiz S1–S2.
91. Puttonen S, Viitasalo K, Harma M. The relationship between current and former shift work and the metabolic syndrome. Scand J Work Environ Health 2012; 38: 343–348.
92. Moller Pedersen SF, Jepsen JR. The metabolic syndrome among Danish seafarers. Int Marit Health 2013; 64: 183–190.
93. Chaput J-P, Despres J-P, Bouchard C, Tremblay A. Short sleep duration is associated with reduced leptin levels and increased adiposity: results from the Québec Family Study. Obesity 2007; 15: 253–261.
94. Wright KP, Jr., Drake AL, Frey DJ et al. Influence of sleep deprivation and circadian misalignment on cortisol, inflammatory markers, and cytokine balance. Brain Behav Immun 2015; Jan 29, pii: S0889-1591(15)00006-9. doi: 10.1016/j.bbi.2015.01.004 [Epub ahead of print].
95. van Cauter E, Spiegel K, Tasali E, Leproult R. Metabolic consequences of sleep and sleep loss. Sleep Med 2008; 9 (suppl. 1): S23–S28.
96. Horne J. Habitual 'short sleep': six hours is 'safe'. J Sleep Res 2010; 19 (1 Part 1): 119–120.
97. Hemio K, Puttonen S, Viitasalo K, Harma M, Peltonen M, Lindstrom J. Food and nutrient intake among workers with different shift systems. Occup Environ Med 2015 Apr 20, pii: oemed-2014-102624. doi: 10.1136/oemed-2014-102624 [Epub ahead of print].
98. Kubo T, Oyama I, Nakamura T et al. Retrospective cohort study of the risk of obesity among shift workers: findings from the Industry-based Shift Workers' Health study, Japan. Occup Environ Med 2011; 68: 327–331.
99. Gan Y, Yang C, Tong X et al. Shift work and diabetes mellitus: a meta-analysis of observational studies. Occup Environ Med 2015; 72: 72–78.
100. Mohren DC, Jansen NW, Kant IJ, Galama J, van den Brandt PA, Swaen GM. Prevalence of common infections among emplyees in different work schedules. J Occup EnvironMed 2002; 44: 1003–1011.
101. Virtanen M, Jokela M, Nyberg ST et al. Long working hours and alcohol use: systematic review and meta-analysis of published studies and unpublished individual participant data. BMJ 2015; 350: g7772.
102. Stevens RG, Hansen J, Costa G et al. Considerations of circadian impact for defining 'shift work' in cancer studies: IARC Working Group Report. Occup Environ Med 2011; 68: 154–162.
103. Kubo T, Oyama I, Nakamura T et al. Industry-based retrospective cohort study of the risk of prostate cancer among rotating-shift workers. Int J Urol 2011; 18: 206–211.
104. Anund A, Fors C, Kecklund G, van Leeuwen W, Akerstedt A. Countermeasures for fatigue in transportation: a review of existing

methods for drivers on road, rail, sea and in aviation. Report no. VTI 852 A. Reg. No. VTI 2015/036-8.2. Stockholm 2015.
105. Caldwell JA, Caldwell JL, Schmidt RM. Alertness management strategies for operational contexts. Sleep Med Rev 2008; 12: 257–273.
106. Shipping and rest: how can we do better? Contract No.: ISBN 978-87-92084-05-7, Seahealth, Copenhagen 2010.
107. Houtman I , Miedema M, Jettinghoff K, Starren A, Heinrich J, Gort J. Fatigue in the shipping industry. Contract No.: 20834/11353, TNO Kwalitet van Leven KvL, Hoofddorp 2005.
108. Allen P, Wadsworth E, Smith A. The prevention and management of seafarers' fatigue: a review. Int Marit Health 2007; 58: 167–177.
109. Wegner R, Felixberger FX, Nern E et al. Projekt 18-Mann-Schiff. Ergebnisse arbeitsmedizinischer Untersuchungen bei Seeleuten auf Shiffen verschiedener besatzungsstärken im Tansatlantikverkehr 1979–1981. Baur X ed. Graciela Madrigal, Hamburg 2008.
110. Hartzler BM. Fatigue on the flight deck: the consequences of sleep loss and the benefits of napping. Acid Anal Prev 2014; 62: 309–318.
111. Taillard J, Capelli A, Sagaspe P, Anund A, Akerstedt T, Philip P. In-car nocturnal blue light exposure improves motorway driving: a randomized controlled trial. PLoS One 2012; 7: e46750.
112. Philip P, Taillard J, Moore N et al. The effects of coffee and napping on nighttime highway driving: a randomized trial. Ann Intern Med 2006; 144: 785–791.
113. Sagaspe P, Taillard J, Chaumet G, Moore N, Bioulac B, Philip P. Aging and nocturnal driving: better with coffee or a nap? A randomized study. Sleep 2007; 30: 1808–1813.
114. Ferguson SA, Lamond N, Kandelaars K, Jay SM, Dawson D. The impact of short, irregular sleep opportunities at sea on the alertness of marine pilots working extended hours. Chronobiol Int 2008; 25: 399–411.
115. Steffen MW, Hazelton AC, Moore WR, Jenkins SM, Clark MM, Hagen PT. Improving sleep: outcomes from a worksite healthy sleep program. J Occup Environ Med 2015; 57: 1–5.
116. MARTHA. Available from: http://www.sdu.dk/en/om_sdu/institutter_centre/ist_sundhedstjenesteforsk/forskning/forskningsenheder/maritimsundhedsikkerhed/nyheder/martha.
117. Liira J, Verbeek JH, Costa G et al. Pharmacological interventions for sleepiness and sleep disturbances caused by shift work. Cochrane Database Syst Rev 2014; 8: CD009776.
118. Dawson D, Ian Noy Y, Harma M, Akerstedt T, Belenky G. Modelling fatigue and the use of fatigue models in work settings. Accid Anal Prev 2011; 43: 549–564.
119. Barnett M, Peckan C, Gatfield D ed. Fatigue management: Self regulatory activities in shipping. 2nd International Conference on Maritime Incidents and Near Miss Reporting; 2013; Kotka.
120. MARTHA. Available from: http://www.warsashacademy.co.uk/about/our-schools/maritime-research-centre/horizon-project/martha.aspx.