

UNIVERSITY OF SOUTHERN DENMARK

# **The psychosocial work environment and fatigue in Danish ferry shipping**

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PhD Thesis

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# List of papers

The present PhD thesis is based on the following papers.

## Paper 1

Dohrmann S. B., Leppin A. (2017). Determinants of seafarers' fatigue: a systematic review and quality assessment. *International Archives of Occupational and Environmental Health*. 90 (1), 13-37. DOI: 10.1007/s00420-016-1174-y

## Paper 2

Dohrmann SB, Christiansen JM, Herttua K., Leppin A. Is physical and psychosocial work stress associated with fatigue in Danish ferry ship employees? *International Journal of Occupational and Environmental Health*. *Submitted*.

## Paper 3

Dohrmann SB, Herttua K, Leppin A. Fatigue in ferry shipping employees: the role of work-family conflict and supervisor support. *International Archives of Occupational and Environmental Health*. *Submitted\**

\*in a slightly revised version than appears in the appendix.

# Abbreviations

COPSOQ:	Copenhagen Psychosocial Questionnaire
ILO:	International Labor Organization
IMO:	International Maritime Organization
LE:	Lack of Energy
LM:	Lack of Motivation
M:	Mean
PD:	Physical Discomfort
PE:	Physical Exertion
S:	Sleepiness
SOFI:	Swedish Occupational Fatigue Inventory



# Summary

## Background

In general fatigue is a state in which the human organism is incapable of maintaining the original level of activity or mental processing due to prior physical, emotional or mental activity and/or absence of insufficient rest (1, 2). Work-related fatigue has been linked to ill health and endangerment of occupational safety, and in ferry shipping employees' fatigue can lead not only to poor individual health and wellbeing but also to accidents, which can potentially jeopardize passengers' safety.

## Objective

Due to the risk of fatigue in the ferry shipping industry – and a lack of prior research on this topic - the main aim of this PhD study was to investigate the link between fatigue and working environmental factors among ferry shipping employees. The investigation specifically focuses on the role of psychosocial factors, as there is a distinct lack of research on such determinants in a seafaring context, and it has resulted in three papers, which have assessed the present empirical evidence on determinants of seafarers' fatigue in a systematic review and examined the association between five domains of fatigue and physical- and psychosocial exposures with a cross-sectional survey among employees of two Danish ferry shipping companies.

## Methods

A systematic review and quality assessment of the empirical evidence was conducted as an initial step to summarize and analyze what was known about fatigue-determining factors in seafaring, the results of which were published in article 1. Two further articles were based on a quantitative, cross-sectional observational study investigating the association between fatigue and the exposure to physical- and psychosocial working environmental factors. Data was collected with the help of a standardized self-report questionnaire

among crew members and those working in the terminals of two Danish ferry ship companies from April to the end of September 2015. 513 employees were invited to the study (179 terminal workers and 334 crew members) and 193 returned a completed questionnaire yielding an overall response rate of 38 %. Fatigue was measured with the Swedish Occupational Fatigue Inventory (SOFI), a five-subscale instrument of which two subscales are considering psychological aspects of fatigue, another two physical aspects of the construct and the remaining one sleepiness. The Copenhagen Psychosocial Questionnaire (COPSOQ) was used for measuring four psychosocial domains of exposure, while single-item questions were used for measuring physical work stressors. The association of risk factors with fatigue was determined using hierarchical multiple linear regression analyses, testing for confounding, interaction and mediation.

## **Results**

For the review, published in article 1, a total of 102 eligible studies were initially identified through systematic database searches. From reviewing the abstracts 83 articles were excluded, the main reason for exclusion being that fatigue not the outcome variable (article 1). Studies showed that poor sleep quality and being sleep-deprived have an adverse effect on fatigue. Additionally, night shifts and -watches are more fatiguing compared to day shifts and day- evening watches. Further, working in the 6h on-6h of watch system is associated with higher fatigue compared to the 4h on-8h of system, and fatigue was found to increase over watch/shift-time – a tendency that was also recognized for tour length. Surprisingly, only very few studies investigated the influence of the physical or the psychosocial working environment on fatigue, which made summarizing of evidence in this area seem premature.

Article 2 and 3 present the results of a cross-sectional study among Danish ferry ship employees. Main findings of article 2 were that job demands and job control were more important for fatigue than disturbance from the physical working environment, and effects

tended to be stronger for psychological than for physical aspects of fatigue. In particular, higher levels of demands were related to higher levels of fatigue on four of the five SOFI-subscales, i.e. lack of energy, physical exertion, lack of motivation and sleepiness, respectively, while a negative association was found between job control and the three psychological sub-dimensions of fatigue. Contrary to this, there was no support for a demand-control interaction. Furthermore, all effects of demand and control on fatigue were at least partly mediated by sleep satisfaction. Article 3 reports findings for the association between experience of work-family conflict, perceived supervisor support and the five subscales of SOFI. Higher levels of work-family conflict went along with higher levels in all aspects of fatigue except for physical exertion. Higher levels of supervisor support, on the other hand, were associated with lesser fatigue in three sub aspects of fatigue; lack of energy, physical exertion and lack of motivation.

## **Conclusion**

The findings presented in this thesis suggest that besides the negative impact on seafarers' fatigue from factors such as insufficient sleep, night work and working in 6h on-6h of watch system, which is well-established according to the scientific literature, the psychosocial work environment may play an important role, particularly for psychological fatigue. In particular job demands, and job control, which so far have been shown to be highly relevant in land-based occupations, were identified as potential determining factors for ferry ship employees' fatigue. Further, beyond a general role of work demands, the more specific problem of work-family conflict as well as of supervisor support were identified as potentially important factors for fatigue experience. The results of this thesis suggest that work-site interventions which particularly aim at a good balance between work and family life, increase employee control and promote good leadership practices in the ferry ship industry may have potential as effective interventions against fatigue among its employees.

# Summary in Danish

## Baggrund

Fatigue er en tilstand, hvor den menneskelige organisme som følge af forudgående fysisk, følelsesmæssig eller mental aktivitet og/eller mangel på tilstrækkelig hvile, er ude af stand til at opretholde det normale aktivitetsniveau uden brug af ekstra ressourcer, som for eksempel koffein. Undersøgelser har vist, at arbejdsrelateret fatigue kan påvirke de ansattes sundhed og trivsel og sikkerheden på arbejdspladsen. Fatigue blandt ansatte i færgefarten er af særlig betydning, da det ikke blot påvirker de ansattes sundhed og sikkerhed, men også har betydning for passagerernes sikkerhed.

## Formål

Det overordnede formål med afhandlingen har derfor været at undersøge sammenhængen mellem fatigue og arbejdsmiljømæssige faktorer blandt ansatte i færgefarten. Da fysiske- og psykosociale arbejdsmiljøfaktorer endnu kun er sparsomt undersøgt i en maritim kontekst, har afhandlingen fokus på netop disse faktorer. Afhandlingen omfatter tre artikler, som har søgt at sammenfatte den eksisterende viden om risikofaktorer for fatigue blandt ansatte i søfarten samt at undersøge sammenhængen mellem fatigue og fem grupper af fysiske- og psykosociale arbejdsrelaterede faktorer.

## Metode

En systematisk gennemgang og kvalitetsvurdering af den videnskabelige litteratur omhandlende risikofaktorer for fatigue hos søfarende blev indledningsvist sammenfattet i den første artikel. De to efterfølgende artikler var baseret på et kvantitativt tværsnitsobservationsstudie, som havde til formål at undersøge sammenhængen mellem eksponeringen for de udvalgte arbejdsmiljøfaktorer og fatigue. Data blev indsamlet ved hjælp af et standardiseret og selvadministreret spørgeskema blandt de ansatte hos to danske færgerederier. Dataindsamlingen fandt sted fra april 2015 til september samme år,

og både besætningsmedlemmer og de der arbejder i de tilhørende terminale var inviteret til at deltage. I alt blev 513 ansatte inviteret til at deltage i undersøgelsen (179 terminalarbejdere og 334 besætningsmedlemmer), og 193 returnerede et udfyldt skema, hvilket resulterede i en svarprocent på 38 %. Graden af oplevet fatigue blev målt ved hjælp af the Swedish Occupational Fatigue Inventory (SOFI). SOFI består af fem subskalaer, to af disse måler psykologiske aspekter af fatigue, to måler den fysiske oplevelse, mens den femte og sidste måler træthed. The Copenhagen Psychosocial Questionnaire (COPSOQ) blev anvendt til at måle de psykosociale eksponeringsområder, mens de fysiske faktorer blev målt ved hjælp af single-item spørgsmål. Hirarkisk multiple lineær regressionsanalyse blev anvendt til at undersøge sammenhængen mellem de fysiske og psykosociale risiko faktorer.

## **Resultater**

102 studier blev indledningsvist vurderet til at være kvalificeret til at indgå i litteraturgennemgangen. Ud fra gennemlæsningen af abstrakterne blev 83 artikler dog ekskluderet fortrinsvis fordi det viste sig, at fatigue ikke indgik i analyserne som den afhængige variable. Gennemgangen af de inkluderede studier viste, at dårlig søvnkvalitet og berøvelse af søvn havde en negativ indflydelse på graden af fatigue, hvilket også var tilfældet for nattevagt og natholdsarbejde. Desuden viste gennemgangen, at det at arbejde i et '6 timer på-6 timer fri' vagtsystem er mere udmattende sammenlignet med '4 timer på-8 timer fri' systemet, og at graden af fatigue steg henover en vagt/et skift samt henover en tur. Antallet af studier som undersøgte sammenhængen mellem fysiske og psykosociale arbejdsmiljøfaktorer viste sig at være forbavsende få.

I artikel 2 og 3 præsenteres resultaterne fra tværsnitsundersøgelsen af fatigue blandt ansatte i Dansk færgefart. De vigtigste fund fra den anden artikel er, at krav og kontrol i arbejdet har større indflydelse på fatigue end forstyrrelse fra det fysiske arbejdsmiljø, og at krav og kontrol synes at have en større effekt på de psykologiske aspekter af fatigue og

træthed sammenlignet med dets fysiske aspekter. Således var høje krav i arbejdet forbundet med en højere score på fire ud af de fem fatigue subskalaer; lack of energy, physical exertion, lack of motivation and sleepiness, respektivt, mens høj kontrol var forbundet med lavere score på lack of energy, lack of motivation og sleepiness. Omvendt blev der ikke fundet indikation for at kontrol har en moderator effekt på krav i forhold til fatigue. Derimod viste resultaterne, at tilfredshed med søvn har en delvist mediator effekt i sammenhængen mellem krav- og kontrol-scorerne og graden af fatigue på samtlige fem subskalaer. I den tredje artikel rapporteres undersøgelsen af sammenhængen mellem arbejde-familie konflikt, supervisor support og de fem fatigue subskalaer. Et højere niveau af arbejds-familie konflikt var forbundet med højere niveauer på samtlige fatigue subskalaer, mens der var en negativ sammenhæng mellem denne faktor og tilfredshed med søvn. Omvendt var høj grad af supervisor support forbundet med mindre fatigue samtlige subskalaer

## **Konklusion**

Resultaterne fra denne afhandling viser, at faktorer som utilstrækkelig søvn og at arbejde om natten samt i '6 timer på-6 timer fri' systemet ifølge litteraturen er forbundet med øget risiko for fatigue blandt søfarende. Videre viser resultaterne, at det psykosociale arbejdsmiljø med sandsynlighed spiller ind i forhold til især de psykologiske aspekter af fatigue blandt de ansatte i færgefarten. Særligt krav og kontrol i arbejdet viste sig at være potente risikofaktorer, hvilket er i overensstemmelse med resultater fra landbaserede erhverv, mens også arbejds-familie konflikt og supervisor support fremstår som faktorer, der kan øge risikoen for fatigue blandt færgefartens ansatte. På baggrund af resultaterne forslås det derfor, at arbejdspladsinterventioner som sænker kravene og øger graden af kontrol i arbejdet samt skaber en god balance mellem arbejde og familieliv samtidig med, at der skabes et udgangspunkt for god ledelsesmæssig praksis i rederierne vil kunne bidrage til at reducerer graden af fatigue blandt ansatte i færgefarten.

# 1.0 Introduction

## 1.1 Why the work environment is a health concern

As accentuated by the WHO statement that

*'Health is created and lived by people within the settings of their everyday life, where they learn, work, play and love' (3),*

work is inextricably linked with health, and the health promoting potential of creating supportive working environments is potent. A potential that is illustrated by the following sentences:

*'Changing patterns of life, work and leisure have a significant impact on health. Work and leisure should be a source of health for people. The way society organizes work should help create a healthy society' (3).*

This is underlined by the fact that globally there are 2.3 million deaths annually from work-related diseases, (2.0 million) and injuries (0.3 million), and economic costs vary between 1.8 and 6.0% of GDP in country estimates (4). The number of fatal work-related diseases and injuries in 2007 was estimated to be more than 53.000 and 5.600, respectively, in the USA, with cost estimates between \$ 46 billion and \$ 6 billion (5). In Denmark, each year more than 2000 employees, 85 % of who are males, die from a work-related illness and 50, again 80 % of who are males, die from an occupational accident (6). Further, Danish society loses almost 64 billion Danish kroners (equivalent to \$ 9 billion) per year due to occupational injuries, absenteeism, lost production and economic spending in health care (7). Thus, it is evident that optimizing the work environment is a vital investment - for society, the industry and not at least for the employees themselves.

The work environment involves the physical geographical location as well as the immediate physical surroundings of the workplace. It further encompasses the working rules and conditions (e.g. time of work, number of work hours), all physical, chemical, biological and psychological factors involved in the work process (e.g. noise, heat/cold, cleaning products, microbes, perceived job demands and job control) as well as the social relationships that employees are influenced by and engaged in in relation to work. Furthermore, the working environment includes health or safety promoting programs and strategies as well as preventive initiatives which aim to prevent accidents or injuries (6).

In earlier days' exposures and effects of a more physical nature, like physical and toxicological hazards and death, injuries and somatic illness, received most attention – by research as well as in terms of work-site interventions (8). In high-resource countries these hazards have increasingly been reduced or controlled over the last decades, but also lost some of their relevance due to a shift towards non-manual work which in general also has led to a stronger focus towards psychological work environment exposures and mental health effects (9). This has been exemplified by the Work Demand-Control (-Support) model, which was developed in the late 1970s by Karasek and colleagues (10, 11). The model states that job demands and job control (together with colleague and supervisor support) influence employees' health and wellbeing (10, 11) and a considerable body of research has tested its hypotheses on a broad array of outcomes (9, 12-14). Other models, then the Demand-Control model, exist and have been used in investigating the mental health effects of psychological work environment exposures, such as the Effort-Reward model (15) (see subchapter '4.1.1 The Demand-control (-support) model' for more details).

There is a general agreement that the effects from work environment exposures, especially those of a psychological nature, on human health and wellbeing are diverse and complex. Signs and symptoms can be diffuse and are mostly dependent on intensity of exposure. Further, progress of work-induced distress can be affected by more than one



single factor, and the latency time can be several to many years. Therefore, it is challenging to determine causal relationships and the significance of and interplay between different individual contributing factors (6).

Among health-related outcomes, fatigue has received increasing attention in occupational (mental) health research in recent years (16, 17). In general, fatigue is a condition in humans that is recognized as a decreased ability to perform activities at the desired level due to exhaustion of mental and/or physical strength (1). For a more detailed elaboration on fatigue, please see chapter 2.0 The concept of fatigue. Occupational fatigue has been found to be highly problematic. Thus, in the working population fatigue has been associated with physical discomfort, pain and illness (1, 18-20) and cognitive degradation (1). Consequently, workers with fatigue have been found to be more likely to experience work absenteeism and work disability compared to non-fatigued workers (21-23), and in the US costs of lost productive time in fatigued workers has been-estimated at \$ 101.0 billion per year compared with workers without fatigue (23). Furthermore, evidence has been found in support of a relationship between fatigue and errors, accidents and injury (1, 24, 25), and the one year incidence of being injured in an occupational accident was found to be almost twofold among fatigued workers as compared with non-fatigued workers (26).

## **1.2 Fatigue as a health concern in seafaring**

In the sea-transport industry, fatigue and its potential impact on health and safety are also increasingly being acknowledged (27, 28). Seafarers' fatigue has recurrently been identified as either the primary cause or as a major contributory factor to maritime accidents in as many as 80 % of all incidents (29). Fatigue has also been found to be associated with the safety of the crews, the ship and the environment (28, 30-33). For instance, fatigue was identified as one of the major causes when the oil tanker Exxon-

Valdez struck Prince William Sound's Bligh Reef, Alaska, in 1989 and spilled about 11 million US gallons of crude oil into the waters (34).

Particularly in ferry shipping, fatigue is extremely hazardous as it jeopardizes passengers' safety. This hazard can be illustrated by the foundering of MS Herold of Free Enterprise in 1987 in the British Channel, causing 183 passengers and crew members to drown (35) and is further underpinned by a report from Cardiff University, UK which revealed that almost one third of the ferry ship crew members reported that they had been involved in a fatigue-related incident or accident (36). Additionally, almost 89% of crew members stated that tiredness had led to loss of concentration (36). The same tendency has also been recognized in a US study. Thus, 74 % of crew members of a US state ferries system reported that they felt tired at work at least 2-3 times per week and as many as 23 % reported that they had fallen asleep at work more than once over a month (37). In addition, 19 % had made errors of judgement due to fatigue, and another 19 % had experienced near misses, i.e. unplanned events that have the potential to cause, but did not actually result in injuries or damages, in which fatigue was a major factor (37). Given the unfavorable outcome of fatigue for crew, passengers and ship companies it becomes evident that there may be a need for preventive programs in the ferry shipping industry.

A first step towards preventive programs in ferry shipping is knowledge on what determines fatigue (28, 30, 38, 39). Factors, like shift schedules, watch systems and irregular working hours, have so far been suggested as possible determinants but results so far have lacked consistency (28, 30, 40, 41). To support future effective preventive programs research on potential determinants, other than shift schedules and watch systems is needed. In land based occupations psychosocial work environmental factors, such as job demands and job control have been found to be associated with greater fatigue (42-45), and found as significant predictors for the onset of fatigue in an onshore

based working population (46). Therefore, these factors seem to hold potential as preventive agents and ought to be investigated further in a ferry shipping context.

### **1.3 Prevalence of fatigue**

Brief episodes of fatigue have been found to be prevalent in 5-45 % of the general population in Scotland, Sweden, the UK and the US among other countries (47, 48), while 2-11 % have reported prolonged fatigue (48). In an occupational context rates for shorter-term fatigue ranging between 12-38 % were found for the US and Norwegian work-force (23, 49), while 22 % of workers reported fatigue of a longer duration in the Netherlands (50). In the same Dutch study one-year incidence was 12 % (50). Fatigue may also be among the symptoms of certain physical diseases or psychological disorders, such as cancer or depression. Thus, fatigue has been found to be prevalent in 27-100 % of patients from the US and the UK among others with somatic diseases (48) and in 16-24% of patients with psychiatric disorders (47), while 0.007- 2.8% from the general population in UK, US and Australia have reported chronic fatigue syndrome (51, 52).

Measures of fatigue in seafaring have mainly focused on fatigue of a more short-term nature, and rates between 38-76 % have been observed in seafarers working on Lithuanian, US and UK vessels (30, 53, 54). These rates are comparable with other lines of the transportation industry, such as aviation, where 75-90% of pilots from different nationalities reported fatigue of a more acute nature (55, 56), and of these 81% stated that their fatigue symptoms were worse than two years prior to the current assessment (55).

## 2.0 The concept of fatigue

### 2.1 General perspectives on fatigue

Fatigue is, first of all considered a normal reaction to prolonged intense activity, and it is often described as a sense of extensive tired- or sleepiness (48). However, this is an oversimplified portrayal of the concept (2, 47).

Fatigue can be classified as passive or active fatigue (57). Active fatigue is a consequence of overstimulation, such as constant, unavoidable work-related demands which require attention and adjustments/actions, while passive fatigue results from under stimulation, such as for instance work-related monitoring of an (unchanging) display for a longer period of time (57). Further, a distinction between central and peripheral fatigue has been suggested, where central fatigue involves malfunction of the central nervous system and the latter involves malfunction of the peripheral nervous system (48, 58).

It has been proposed, however, that the most useful classification distinguishes acute and chronic fatigue (59). *Acute fatigue* - also referred to as “normal”, short term or non-pathological fatigue – is linked to an identifiable cause, which is often related to intense physical or mental activity or flu-like illness, and episodes last for less than three consecutive months. Acute fatigue is self-limited or alleviated by the right initiatives, such as sufficient rest or treatment of/relief from the underlying condition or illness, and has only a minor impact on daily life activities and quality of life (47, 59, 60). Though, if not successfully dealt with, acute fatigue has been suggested as a precursor of a more chronic condition (61).

In contrast, *chronic fatigue* – or pathological fatigue – is experienced with a greater intensity and much more likely to affect daily activities and quality of life of the individual. It is of a longer duration compared to acute fatigue, i.e. three months or more, and it

cannot or can only partly be relieved by rest or other restorative interventions (47, 59, 60). In terms of causality, chronic fatigue is recognized as a major symptom of certain somatic diseases, particularly cancer, but at the same time also as a consequence of some medical treatments, such as in cancer. Further, psychiatric illnesses, such as depression, can be associated with experience of chronic fatigue, even though it often remains unclear to which extent the occurrence of depression is a cause or a result of fatigue experience (60, 62). Chronic fatigue syndrome, or myalgic encephalomyelitis, on the other hand, is not due to another, primary medical condition. This syndrome is characterized by long-term extreme fatigue and other non-specific symptoms, such as muscle pain, pain in multiple joints, impaired memory or concentration and sore lymph nodes. Chronic fatigue syndrome is not resulting from ongoing exertion, is not substantially alleviated or relieved by rest, and often severely inhibits a person's capacity to function in daily life and carry out responsibilities (16, 61, 62).

## **2.2 A definition of fatigue**

Defining fatigue is therefore challenging, and different definitions have been proposed over the years, but are often found to be inadequate – in general – but not least in an occupational context - as many tend to fail to identify vital aspects of the concept, such as, for instance, if the term fatigue is to be treated as acute fatigue or if it reflects a longer-term, accumulated physical, psychological, cognitive or mental impairment (2). However, there seems to be a general consensus among researchers and professionals that occupational fatigue is a multidimensional construct that can best be seen as referring to a transition state (17, 47, 57, 58, 63-65).

In an occupational context, the following definition for fatigue was proposed and recommended to meet previous shortcomings: “Fatigue refers to a state of an organism’s muscles, viscera, or central nervous system, in which prior physical activity and/or mental processing, in the absence of sufficient rest, results in insufficient cellular capacity or

system wide energy to maintain the original level of activity and/or processing by using normal resources” (2).

This definition accounts for vital facets of fatigue which briefly can be divided into the *sensation* of fatigue, that is insufficient cellular capacity or system wide energy, the *cause* of this sensation, that is prior physical activity and/or mental processing (in the absence of sufficient rest), and the *change* that is required in the organism regarding activity and/or mental processing to continue the task, that is to maintain the original level of activity and/or processing by using normal resources (2).

As occupational fatigue is the primary concern in this thesis, the definition proposed by Soames-Job and Dalziel (2) was chosen as guidance of the work. This definition conceives of fatigue as having a more acute nature, and distinguishes physical and mental fatigue. Physical – sometimes also referred to as muscular - fatigue is related to longer periods of physical activities or performance of tasks, such as high intensity work. Such performance causes a decreased ability to perform (these) activities/tasks at the desired level due to exertion of physical (muscle) strength, physical discomfort and/or a more general feeling of lack of energy. Mental fatigue is first and foremost a consequence of mental strain or intense emotional experiences, such as perceived lack of control over tasks (e.g. work-related tasks), and the way they are performed. Such strain or experience is associated with decreased energy and/or motivation to continue performing a task and/or decreases in vigilance and in ability to process and respond to information. Furthermore, mental fatigue can be expressed in terms of subjective sleepiness (1, 58).

### **3.0 Determinants of fatigue: physical work environment, work organization and personal factors**

While the body of literature on the subject of fatigue has brought forward a somewhat better understanding of this concept and its work-related consequences, many issues remain unsolved. In particular, there still is insufficient knowledge about the causes of fatigue in an occupational context. In general terms, such risk factors can be split into predisposing factors, such as female gender, precipitating factors, such as an acute physical stressor (e.g. a virus infection), psychological stressor (e.g. divorce) or social stressor (e.g. work-related reduction in rank), and perpetuating factors, such as physical inactivity or ongoing physical stress (high disturbance from the physical work environment in terms of noise, temperature or vibrations), psychological stress (e.g. workplace-related bullying) or social stress (e.g. living in a deprived neighborhood) (1, 17, 62, 63). The following paragraphs include a brief overview of research findings on work-related risk factors of fatigue. It should be noted, though, that since no clear distinction between acute and chronic fatigue was made in the reviewed studies, as each risk factor is likely to be associated with more than one aspect of fatigue, this presentation neither attempts to further specify fatigue.

Up till now much research on the factors determining work place-related fatigue has focused on shift work, especially time of shift, and to some extent also on sleep-related factors (66-69). Shift work has been found to increase the risk of fatigue (70), and *long shift duration* in particular was identified to be very fatiguing (1, 71-76), especially when comparing a 12 -hour system to an 8-hour one (77), though this evidence is not unequivocal (72, 77, 78). In this line, research has also shown an association between *overtime*, defined as the amount of work time in a week that exceeds 40 hours (mandatory as well as voluntary) and higher levels of fatigue. Specifically, more than 20 hours of overtime per week has been found to be the point after which recovery from fatigue becomes difficult (1). Further, *a non-fixed shift pattern* constitutes a higher fatigue risk

compared to a fixed one, and this effect is stronger when night work is included (76). In relation to night work, research consistently supports that fatigue is particularly pronounced during *night shifts* compared to day shifts, though also (early) morning and evening shifts have been found to constitute a higher risk (64, 70, 72-76, 79-83). Work carried out throughout the biological night seems to create a misalignment in the circadian process, which affects alertness levels on the job and the ability to rest and sleep at home (67, 84, 85). This might also explain that the risk of fatigue increases with *day time sleep* compared to sleep during nights (76). Besides the influence from time of sleep and work, research has also shown that *insufficient sleep length* is associated with an increased risk of fatigue (66, 74-76, 86) – which is also the case for *poor sleep quality* (45).

Although an association between fatigue and shift work, time and quantity of work and quantity and quality of sleep are undisputed, the view that ‘it is all about shift and sleep’ tends to overlook other types of potential risk factors (66). Among such factors are, for instance, *personal characteristics*. Thus, for example higher levels of fatigue have been found among females (84) and among those who were more likely to experience negative emotions (1). Also, an influence of age has been investigated, and while some studies found no effect (46) others interestingly reported higher age to be associated with a decreased risk of fatigue (45, 75), arguing that this may be due to lesser experience among the younger aged employees which might make up for a subjectively more strenuous work experience (87). Risk factors also include *health status*. For example - as outlined in the chapter ‘2.0 The concept of fatigue’ – research supports that suffering from psychological disorders, like depression or anxiety, is associated with higher levels of fatigue (1, 50). *Lifestyle characteristics* might further be relevant as moderate physical activity has been found to be protective of fatigue (87), while physical inactivity has been identified as a predictor of its onset (88). Alcohol consumption may also increase the risk of fatigue (87). However, another study reported that abstainers had a significantly higher prevalence of fatigue, and that lack of any alcohol consumption predicted the onset of fatigue in men



after one year follow up (88). The same study also showed that smokers had a significantly higher prevalence of fatigue compared to non-smokers (88). In addition, overweight male respondents were at higher risk of fatigue (88). Overweight was also found to be a predictor of the onset of fatigue in men after one year follow up, but the overall picture was complex as it also turned out that it was underweight which predicted the onset of fatigue in women (88).

Yet another group of risk factors is made up by *physical work environment factors*, such as noise, vibrations and high temperatures which are all environmental factors that have been linked to fatigue (1). Thus, intraoperative noise, i.e. noise in operation theaters, was found to increase fatigue (89). In line with this, older employees who were exposed to higher traffic- related noise levels during work felt more fatigued compared to their younger counterparts (90). In yet another study, which compared three occupational groups, fatigue was more common among the noise-exposed groups – in particular those groups with the highest level of exposure (91). Fatigue has also been shown to be resulting from the duration of noise exposure (91). Moreover, research provides support for a positive association between heat exposure (92-94) as well as whole body vibration and fatigue (93).

In general, it should be noted, however, that this evidence has to be considered as tentative since many of the reviewed studies are cross-sectional so that no definite conclusions on a causal relationship between potential risk factors and fatigue can be drawn.

## **4.0 Determinants of fatigue: psychosocial factors**

The psychosocial working environment is generally considered to be one of the most important work-related issues in contemporary and future society (95, 96). While a generally accepted definition of 'psychosocial work environment' still does not seem to exist five requirements for a positive psychosocial work environment appear to be generally acknowledged (96): 'Work should be arranged in a way which allows the individual worker to influence his own working situation, working methods and pace', 'Work should be arranged in a way which allows for an overview and understanding of the work process as a whole', 'Work should be arranged in a way which gives the individual worker possibilities to use and develop all his human resources', 'Work should be arranged in a way that allows for human contacts and co-operation in the course of work', 'Work should be arranged in a way which makes it possible for the individual worker to satisfy time claims from roles and obligations outside work, e.g. family, social and political commitments' (97).

### **4.1 Theoretical framework**

#### **4.1.1 The Demand-control (-support) model**

The Demand-control model, which has been put forward by Karasek (10) in 1979, aims to explain the occurrence of mental strain in an occupational context in terms of mainly two factors: *job demands and job control*. In a later version of the model *social support*, was added to the initial model as a third factor (11). Demands are typically operationalized in terms of the quantitative aspects of work tasks, such as workload and work tempo or in terms of its cognitive or emotional aspects, such as the need for making difficult decisions or the extent to which workers perceive their work as emotionally demanding or disturbing, respectively. Job control – also termed decision latitude – can be described as the potential influence a worker has over his or her tasks and his or her behavior during a working day. More specifically, control is operationalized in terms of skill discretion, i.e. the

opportunity to use specific job skills in the working process and decision authority, i.e. the extent of decision autonomy in task-related decisions (e.g. timing and methods), whereas the support-dimension is operationalized in terms of help, advice or recognition from nearest superior or from co-workers (10, 11).

Two hypotheses can be drawn from the Control-demand (-support) model. One is the strain hypothesis, which states that there is an increased likelihood of high mental strain when working in a job characterized by a) high demands and low control, or b) high demands and low control plus low support (10, 11). The second is the buffer hypothesis, which claims that a) job control moderates the impact of job demands on mental strain, and/or b) that support moderates the negative impact from a high strain job on mental strain (10, 11, 14, 98). Thus Karasek (10), the main author of the Demand-Control model and a pioneer in the field, found that 'high strain jobs' (high demands and low control) (a) were associated with high mental strain and low job dissatisfaction, and that more active jobs (high demands and high control) were associated with reduced mental strain and higher job satisfaction. Further, Karasek and Theorell (11) also provided evidence for a positive impact of social support on mental strain and job satisfaction.

Another approach than the one offered by the Demand-control model is Siegrist's 'Effort-reward' model (15) which combines extrinsic and intrinsic factors within an integrative model. This model, which also has been widely used in international research on occupational stress since the late 1990's, defines high straining job conditions as a perceived mismatch between job demands and rewards (99). Job demands can be extrinsic or intrinsic, that is be determined for instance by workload/work pressure but also by individual personality traits/coping behavior, respectively, while salary and work-related esteem, job-security and possibilities for job-related development are characterized as rewards. According to the model, an imbalance, i.e. high demands and low rewards, increase the risk of an individual worker to experience negative emotions and stress

responses, such as fatigue, with adverse long-term effects on health. Furthermore, workers who exhibit a specific pattern of coping with high demands, i.e. excessive engagement and a desire of being in control, are expected to be particularly susceptible to these stress responses (15, 99).

With a specific view on fatigue Techera et al. (1) have more recently developed a system model that aims to identify determinants of occupational fatigue, evaluate the relationships among the causal factors, identify outcomes of occupational fatigue, as well as to evaluate the relationships between fatigue outcomes. This work builds on empirical and validated research findings, and nine factors were identified as potential causal factors, while five factors were recognized as possible outcomes. From the meta-analysis, work load, mental exertion, overtime/extended shifts, physical work environment and social environment were identified as causal factors for fatigue, and no interrelations were found between causal factors with one exception, though, as a relationship between overtime/extended shifts and incomplete recovery was identified (1). As for consequences of occupational fatigue significant effects were found for illness and physical- and cognitive degeneration (1). The model surely offers a deeper and more comprehensive understanding of the causes and consequences of occupational fatigue, but as a result of this very comprehensiveness it is too complex to be tested in an empirical study. Therefore, more specific models, which focus on specific factors, such as the Demand-control model, are still needed in research on occupational fatigue.

## **4.2 Empirical evidence**

### **4.2.1 Job demands, job control and support**

In the past 35 years, the Demand-Control (-Support) model and its hypotheses have been applied to a broad array of outcomes, such as measures for health and wellbeing, physical health, sickness absence, lifestyles and mental health. Systematic reviews on this research,

some of them meta-analyses, have more recently been emerging. Three of these have been found to be of special interest as they provide a systematic review of research on the Demand-Control (-Support) model in which they, contrary to others, put emphasize on a distinction between the strain and the buffering hypotheses (12-14), consider causalities (12-14), and methodological quality of studies (13). Therefore, results from these three reviews are presented in the following.

In 1999, van der Doef and Maes (12) published a systematic review including 63 studies on the Demand-control (-support) model and general or job-related psychological wellbeing published between 1997-1997. Ten years later this review was updated and extended by Hausser et al. (14) including findings from 83 studies published between 1998 and 2007. To address the methodological quality of longitudinal research examining the Demand-control (-support) model De Lange et al. (13) reviewed 19 'high quality' (studies that had received a minimum of two stars out of five possible (evaluation based on study design, time lags, measures, method of analysis and non-dependence analysis)) longitudinal studies (out of 45 studies identified) including various outcome variables, like health and wellbeing, sickness absence and cardiovascular disease, published between 1997-2000.

All three reviews found support for main effects of job demands indicating that higher levels of perceived demands were associated with less health and wellbeing, more sickness absenteeism and more cardiovascular disease. In the same vein, main effects for job control and support showed that higher levels of control and support were related to higher levels of health wellbeing, and less absenteeism and cardiovascular disease (12-14). However, while the evidence for a main effect of job demands, job control and support was consistent in cross-sectional studies (12, 14), findings from longitudinal studies were more inconsistent, and reciprocal or reversed causation were suggested to account for part of the association between the demand-control (-support) dimensions and the outcomes under study (14). This interpretation was not supported by De Lange et al. (13)

though, who, in their review of 'high quality' studies, found evidence in support of (unidirectional) causal effects of job demands, job control or support over time on the outcome variables under study.

In contrast, all three reviews found only weak evidence for the buffer hypotheses (a) and b)). Thus, the reviews did not provide strong support for a moderating effect of job control on the negative impact of job demands on the health-related outcomes under study, nor was there any strong indication for a moderating effect from support on the negative impact from a high strain job (12-14). It was suggested, though, that such an effect may depend on whether demand and control are based on identical dimensions or not, rather than that the idea of buffering effects itself is incorrect (12, 14). Thus, studies in which job demands and job control referred to the same level of functioning, such as when demands were operationalized as time pressure or work load and control as task or scheduling control, were more likely to find an interaction effect as compared to studies that were based on global measures (14).

#### **4.2.2 Job demands, job control, support and fatigue**

In recent years, the Demand-control (-support) model has also been tested with respect to fatigue, and large-scale cross-sectional surveys have found support for main effects of all three main factors (43, 100-102), while one also found support for the buffering hypothesis (43). For example, based on data from 11,020 blue and white-collar workers, Bultmann et al. (43) found that higher emotional demands, lower decision latitude, and lower supervisor support and co-workers were significantly associated with higher levels of fatigue among male respondents, while higher psychological demands, lower decision latitude and lower support from supervisor and co-workers turned out to be significant for female respondents. For both genders, it was found that high strain jobs (high demands and low control) and passive jobs (low demands and low control) were associated with higher risk of fatigue compared to low strain jobs (low demands and high control) (43).

Longitudinal relationships between job demands, job control, support and fatigue have also been investigated (44, 46). Based on data from 8833 blue and white-collar workers Bultmann et al. (46), for instance, reported that all baseline scores of demands were found to be positively associated with 1-year-follow up fatigue scores for males, whereas decision latitude and supervisor support and co-workers were negatively associated with 1-year-follow up fatigue scores. For female workers, the same picture emerged, but none of the associations remained significant after adjustment for potential confounders and baseline measures.

In their study including data on 1742 (1-year-follow up: 1163) blue and white-collar workers De Lange et al. (44) showed that workers in stable high strain jobs and in stable active jobs reported higher fatigue levels than those in stable low strain and passive jobs, which indicates that control might not always reduce the impact of high job demands. Further a time by job group interaction effect revealed that workers in stable high strain jobs reported highest levels of fatigue at both time points compared with those in stable passive and low strain jobs (no significant differences were found for workers in stable active jobs) (44). De Lange et al. (44) also found significant across-time changes in fatigue levels for workers who changed from a non-high strain job to a high strain one, while a transition towards a non-high strain job did not show an across-time significant decrease in fatigue levels. In the same vein, other studies reported changes in the perceived levels of job demands, job control and support to be associated with changes in fatigue (103, 104). For instance, based on data from 5256 blue and white-collar workers Janssen and Nijhuis (104) showed that decreased job demands and increased decision latitude and social support resulted in significantly more reduced fatigue scores after 1 year compared with a situation that included no change in job characteristics - an effect that was independent of the initial values of the work characteristics.

### **4.3 Psychosocial factors: work-family conflict**

There is thus strong evidence for an association between job demands, job control and support and workers' health and wellbeing, including support for a relation between these factors and workers' fatigue. However, these studies are based on a single theoretical model and restricted to only very few out of a large range of psychosocial factors (95, 105). Critics of the Demand-control model have pointed to certain deficits of the model, for example by arguing that control may be more important than demands (106, 107), and have suggested that mediating factors, such as self-efficacy, should be taken into account (108). In addition, researchers have argued that also non-work-task related factors, such as income, are of importance in terms of workers' health and wellbeing, and for which the 'Effort-reward model – described in subchapter '4.1.1 The Demand-control (-support) model' - offers an alternative hypothesis. In this line, it has been emphasized that the psychosocial work environmental factors are conditioned and modified by social structures and relations in as well as outside workplaces – structures and relations which are influenced by macro-level economic and political structures (108, 109). A full conceptual framework is too complex to be tested in an empirical study (108), but in order to better understand the influence on workers' health and wellbeing from psychosocial factors it is important that future research examines a broader range of factors and the relationship between them (96).

In general terms, psychosocial factors beyond task-related factors can be categorized into interpersonal relations and leadership (e.g. leader support), work-individual interface (e.g. work-family conflict), and values at the workplace (e.g. justice) (105). Particularly, the work-individual interface and leadership have attracted special attention over the past decade. In many sectors of industry, including ferry shipping, working conditions are often challenging, such as working non-standard times (96, 110, 111), and as a consequence work responsibilities have become more likely to intrude into employees' personal life, resulting in experiences of work-family conflict (112, 113), which has been linked to



negative mental health outcomes (114-116), sleep-related outcomes (117) and fatigue (118, 119). Thus, Ohta et al. (118) found that prolonged fatigue was cross-sectionally associated with work family conflict in a sample of 444 married male Japanese physicians. In the same line, Rahman et al. (119) reported a cross-sectional association between this factor and chronic fatigue from a study among 201 emergency and critical care nurses in Southeast Asia. As for leadership, this factor has been proposed as an important element in reducing work-family conflict (120-122), as well as it has been found to have a positive impact on workers' health and wellbeing (123, 124) and fatigue (49, 125). Further, as has been outlined above, social support, i.e. support from supervisors, colleagues and friends/family has been found to moderate work-stressor (e.g. physical hazards, work-related conflicts and job demands) – strain (e.g. self-reported health and burnout) relationships (124, 126, 127). However, up till now only a very few studies seemingly have investigated a potential moderating effect of leader support on the relationship between work-family conflict and fatigue or fatigue-related outcomes. Thus, Crain et al. (117) investigated the influence from work-family conflict, supervisor behavior and sleep outcomes on a sample of 623 information technology workers, and found that work-family conflict had a negative impact on sleep quality and sleep quantity. In contrast, supervisor behavior was not significantly associated with sleep quality or quantity and neither were there any indications for a moderating effect of supervisor behavior on any of the sleep-related measures (117). Hence, while current evidence suggests an association between work-family conflict and fatigue, the question of more complex relationships with other factors, such as social resources remains as yet unanswered and therefore more research is needed to explore this relationship in greater detail.

#### **4.4 Determinants of fatigue in seafaring**

As mentioned in chapter '1.2 Fatigue as a health concern in seafaring' a range of potential determinants has been suggested for fatigue among seafarers, but results lacked consistency. A systematic description and analysis of what is known about determinants of

seafarers' fatigue and an assessment of this evidence was therefore planned as a first part of the current thesis. The results from this review are presented in the chapter '7.1 Paper 1: Review of determinants of fatigue in seafaring'.

## 5.0 Aim and objectives

Due to the risks involved in fatigue in seafaring - especially in ferry shipping - and the lack of research on the topic in this particular occupational context, and specifically on the role of psychosocial factors, including their potential as preventive agents, the main aim of this PhD study was to investigate the link between fatigue and the work environment with an exclusive focus on psychosocial working environmental factors.

In the pursuit of this aim, an assessment of what is already known about determinants of seafarers' fatigue was first aimed at. Secondly, physical work environmental factors, perceived job demands and work-family conflict were examined as specific work-site stressors, while job control and support from nearest superior were considered as potential resources. The work was guided by the following objectives:

- 1) To systematically review the empirical evidence about determinants of seafarers' fatigue and to analyze the quality of this knowledge (article 1)
- 2) To investigate the association between five sub-dimensions of fatigue and the potential psychosocial work-site stressors 'job demands' (article 2) and 'work-family conflict' (article 3) as well as the resource factors 'job control' (article 2) and 'supervisor support' (article 3), by specifically testing
  - a. main effects of job demand and job control on fatigue (article 2)
  - b. an interaction effect between job demands and job control on fatigue (article 2)
  - c. whether a potential association between job demands and fatigue is mediated by sleep quality (article 2)
  - d. main effects of work-family conflict and supervisor support on fatigue (article 3)

## 6.0 Material and methods

### 6.1 Overview

The PhD work consisted of systematic literature review (article 1) and an original empirical study upon which further two articles were based. A brief overview of the aims, methods, data and study periods of the three papers is presented in table 1 below.

**Table 1. Overview of aims, study design, methods, data and study periods in the three papers**

	<b>Paper 1</b>	<b>Paper 2</b>	<b>Paper 3</b>
Aim	To systematically detect, analyze and assess the evidence on determinants of seafarers' fatigue and to evaluate the quality of this evidence	To investigate the association between physical work, environmental stressors, job demands and job control and different dimensions of occupational fatigue	To investigate the association between work-family conflict, supervisor support and different dimensions of occupational fatigue
Study design	Systematic review	Cross-sectional observational survey	Cross-sectional observational survey
Measurement	NA	Standardized questionnaire	Standardized questionnaire
Data analysis	Systematic narrative literature review	Standard multiple hierarchical linear regression	Standard multiple hierarchical linear regression
Population	Adult seafarers engaged in occupational sailing	Ferry crew members and terminal workers from two Danish ferry ship companies	Ferry crew members and terminal workers from two Danish ferry ship companies
Response rate	19 articles and conference papers out of 102 eligible studies	193 respondents out of 513 eligible employees	193 respondents out of 513 eligible employees
Study period	August 2014 – April 2016	April 2015 – September 2015	April 2015 – September 2015

## **6.2 Paper 1: systematic literature review**

To guide this study a review of the scientific literature was conducted as an initial step to summarize and analyze what was known about fatigue risk factors in seafaring (paper 1). A systematic approach in assessing eligibility, comparing outcomes and assessing risk of bias, guided by the Cochrane Handbook for Systematic Reviews of Interventions (128), was applied. Due to the diversity in study designs and samples an estimation of average effect sizes from these studies by meta-analytic techniques was not feasible (128).

A three-step strategy was applied to identify relevant literature. As a first step, published articles were identified by means of a systematic search in 9 relevant databases using the terms “fatigue”, “determinant”, “seafarer” and their respective MESH terms as search words. The search was limited to studies on human adults (18 years +) described in articles including an abstract and published in English in scientific journals from 1980 to the last day of the search, i.e. April 15<sup>th</sup>, 2016. In a first phase, conference papers were identified by means of a systematic search in Web of Science and the search engine ‘Summon’. Second, a snowball system was used to search the reference sections of all individual articles and papers so far retrieved (129). Further, in a third and final phase, the webpages of known ongoing fatigue- related research projects were checked for relevant publications.

Eligibility for inclusion was based on the following criteria: 1) study participants were seafarers engaged in occupational sailing, 2) one or more research questions about factors associated with seafarers’ fatigue were included, 3) fatigue was assessed in terms of subjective ratings of fatigue, tiredness etc. or alertness and/or in terms of physiological fatigue measurements, while studies relying exclusively on performance measures as indicators for fatigue were not considered, 4) quantitative data were provided, 5) articles were published in English or Danish. Duplicate publications and publications with a sole focus on methodological issues were excluded, as were studies with an exclusive focus on

ergonomic factors, such as type of seats installed on vessels. The process of the article selection is illustrated in more detail in appendix 2.

## **6.3 Papers 2 and 3: Survey study on fatigue in Danish ferry shipping**

Next, a study on the association between fatigue and exposure to physical work environmental factors, perceived job demands, job control, work-family conflict, and perceived supervisor support in ferry shipping was conducted (papers 2 and 3).

### **6.3.1 Study setting**

Denmark consists of the peninsula Jutland and around 1,419 islands bigger than 100 m<sup>2</sup>. Of the 443 named islands, 72 are inhabited. Many of the larger islands are connected to other parts of Denmark or to other countries by bridges, e.g. the Little Belt Bridge connects Jutland and Funen and the Øresund Bridge while the Øresund Tunnel is connecting Sjælland and Skåne in Sweden.

Ferry ships, i.e. ships in regular service, which are designed to transport vehicles and passengers, are connecting the smaller islands. 78 ferry ships are registered under Danish flag, and every 47 seconds a ferry ship departs from or enters into a Danish port, transporting a total of 32 million passengers – locals, visitors and tourists – each year. Thus, ferry services are a vital connection for the Danish islands, and the ships together with their terminals are important places of employment especially in somewhat remote areas. Furthermore, these services are also important assets in generating growth and secondary employment in the local communities (130).

### **6.3.2 Rules and regulations**

In a seafaring context, each individual flag administration is responsible for the development, acceptance, implementation and enforcement of international and national legislations that deal with the various aspects of fatigue: work hours, rest periods, crew competency and watch keeping practice. On the international level the International Labor Organization (ILO) and International Maritime Organization (IMO) have issued conventions and instruments that deal with fatigue aspects. In their convention concerning seafarers' hours of work and manning of ships ILO for instance determine that 'the minimum hours of rest shall not be less than: (i) ten hours in any 24-hour period; and (ii) 77 hours in any seven-day period' (131), and IMO, for instance determines, that seafarers must hold a health certificate and a certificate of competencies (132). In addition to the international standards, companies and flag administration policies must be followed on board all ships (133), please see appendix 1 for details on fatigue-related rules and regulations for Danish flagged ships.

### **6.3.3 Data collection**

Data was collected from April to the end of September 2015, and all crew members and those working in the terminals employed by two Danish ferry ship companies were considered eligible for the study and invited for participation via written information materials.

#### **6.3.3.1 The participating companies**

Two Danish ferry ship companies participated in the study. One was operating a total of five domestic and two international services with a total fleet of 10 ships. Crew members and terminal workers from every service were invited to the study and all of the seven services were represented in the study sample. The company had a total of 229 seafaring and 107 terminal employees. The majority of participants were seafarers of Danish descent

who had changing work hours - about half worked days and evenings, while the remaining half also worked during nights.

The second ferry ship company was operating three international services and on request from the company only one service, with two ships, was invited to the study. Seafaring and terminal employees from that particular service, counting a total n of 105 and 72 respectively, were asked to participate. Participating employees were all of Danish descent and had either day work or changing work hours including day, evening and night work. The majority of participants were from company 1 (81 %), 82 % belonged to the seafaring group of participants, and about half were officers (53 %). For further information about the sample see subchapters '7.2 Paper 2: Fatigue and its association with job demands and job control' and '7.3 Paper 3: Fatigue and its association with work-family conflict and supervisor support' as well as articles 2 and 3.

In agreement with the ferry ship companies the questionnaire was made available electronically in SurveyXact as well as in a printed form. Information about the study was presented at information meetings and made available on the companies' intranet. Secondly, a link to the online questionnaire, including a description of how to get access and fill it out, was 1) made available on the companies' intranet and 2) sent out in emails. Thirdly, paper versions of the questionnaire, together with prepaid return envelopes were distributed to eligible employees by terminal managers and senior captains in order to be able to also reach those who preferred a printed format. Two reminders were sent: 1) via email, three weeks after the questionnaire had been sent and 2) via the terminal managers and senior captains another 3 weeks after. The questionnaire was distributed to 513 employees (179 terminal workers and 334 crew members). 193 returned a completed questionnaire yielding an overall response rate of 38 %. It was tested if the subsample from company 1, which made up the large majority of the study sample (81 %) to test whether participants in the study differed from all crew members and terminal workers



from the respective company in terms of age, gender, workplace (on board of a ferry versus terminal) and professional group (officers/non-officers). No significant differences were found

### **6.3.4 The questionnaire**

The questionnaire was developed to cover main areas deemed relevant for an investigation of the physical and psychosocial working environment in ferry shipping and perceived levels of fatigue among the employees. The questionnaire was divided by topics including *work specific issues* (e.g. workplace), *work environmental conditions* (physical and psychosocial work environmental factors), *conditions of employment* (e.g. years of employment and time of work), *sleep* (e.g. sleep satisfaction), *fatigue, health behaviors* (level of physical activity and smoking), and *socio-demographic factors* (e.g. age and gender). The Swedish Occupational Fatigue Inventory (SOFI) was included as a measurement for the outcome fatigue, and the second version of The Copenhagen Psychosocial Questionnaire (COPSOQ) was used to measure the psychosocial working environmental exposures: demands, control, work-family conflict and support from nearest superior. A more detailed description of SOFI and COPSOQ is presented in the chapter '6.3.5 Outcome measurement' and '6.3.6 Exposure measurement', respectively. All other questions related to work- and employment-related factors came from the Danish survey 'Arbejdsmiljø og Helbred I Danmark 2012-2020' (Work and Health in Denmark 2012-2020) (134), while the health-related questions and information on socio-demographic factors originated from the Danish survey 'KRAM' (Diet, Smoking, Alcohol, Exercise) (135).

### **6.3.5 Outcome measurement**

In papers 2 and 3 fatigue was the main outcome of interest and was assessed using the second, revised version of The Swedish Occupational Fatigue Inventory (SOFI), which has

specifically been developed as a measure of occupational fatigue (64). For the purpose of the present study the English version of SOFI was translated into Danish using translation/back-translation technique (136). SOFI includes 20 items tapping fatigue-related symptoms and feelings which are to be rated on response scales from 0='not at all' to 6='to a very high degree' with regard to how respondents felt when they were most tired when at work during the last four weeks. The instrument involves five sub-dimensions: 1) lack of energy (LE), 2) physical exertion (PE), 3) physical discomfort (PD), 4) lack of motivation (LM) and 5) sleepiness (S). The first sub-dimension reflects a more general aspect of fatigue, the second and the third relate to physical aspects while the last two dimensions tap into mental aspects of fatigue (64, 65). For each of the five subscales a sum score was calculated indicating the symptom-specific perceived level of fatigue (64). Internal consistencies for the subscales were  $\alpha = 0.87$  (LE),  $\alpha = 0.86$  (PE),  $\alpha = 0.86$  (PD),  $\alpha = 0.93$  (LM) and  $\alpha = 0.93$  (S).

### **6.3.6 Exposure measurement**

In paper 2 job demands and job control were the main exposures of interest, while work-family conflict and support from nearest superior were the center of attention in paper 3.

The second version of the Copenhagen Psychosocial Questionnaire (COPSOQ) is a standardized and validated questionnaire that covers a broad range of psychosocial work environmental factors, such as demands, control and support (10), and this questionnaire has become the national standard for assessing psychosocial work environment in Danish workplaces (105). Therefore, all the psychosocial domains of exposures were assessed using COPSOQ. This instrument includes a total of 127 items distributed over 41 subscales, six of which – with a total of 22 items – were used for exposure measures in the present PhD. These subscales were: 'quantitative demands', 'work pace', 'influence at work', 'opportunities for professional development', 'work-family conflict', and 'support from nearest superior'. 'Quantitative demands', 'influence at work' and 'support from nearest

superior' were each to be rated on a five-point scale indicating frequency ('always' to 'almost never/never'), while 'work pace' and 'opportunities for professional development' were each to be rated on a five point scale indicating magnitude ('to a very large extent' to 'to a very small extent'), while a five point scale indicating certainty ('yes, certainly to 'no, not at all') was used in rating 'work-family conflict'. In accordance with guidelines 'quantitative demands' and 'work pace' were added up to a total 'job demands'-scale, and 'influence at work' and 'possibilities for professional development' were added up to a total 'job control'-scale (10, 105). Cronbach alpha coefficients were  $\alpha = 0.77$  for 'job demands',  $\alpha = 0.86$ . for 'job control',  $\alpha = 0.74$  for 'work-family conflict' and  $\alpha = 0.69$  for 'support from nearest superior'.

In addition, 5 single-item questions from 'Arbejdsmiljø og Helbred I Danmark 2012-2020' (Work Environment and Health in Denmark 2012-2020) were used for measuring physical work environment stressors (noise, movements, vibrations, heat and cold) which were to be rated on 5-point frequency scales ('almost all the time' to 'almost never') (134). The five measures were then combined into an overall index by summing up scores on all five items.

### **6.3.7 Covariates**

Selection of covariates was determined in preliminary discussions on potential confounding factors for the job demands/job control/social support–fatigue relationship based on existing empirical evidence, especially in terms of the results from the systematic review (137) but also taking into account the wider literature on occupational fatigue. Age, gender, country of birth, school education (primary-/secondary level), vocational education (vocational training/university college or university), professional group (officers/non-officers), living with a partner (no/yes), children under six living at home (no/yes), ferry ship company (company 1/- 2), workplace (ship/terminal), typical time of work (day and evening/day, evening and night), physical activity (0-4 hours per week, low

intensity/ $\geq$  2 hours per week, high intensity), smoking (no/yes) and sleep quality. Sleep quality was measured in two ways. First, sleep quality was measured as sleep satisfaction on a 10- point rating scale from 'completely satisfied' to 'not satisfied at all' and used in article 2 to test a potential mediating role of this factor. Secondly, sleep problems were measured with the 'sleeping troubles' subscale of COPSOQ, which is a 4-item scale using five-point response formats indicating frequency ('all the time' to 'not at all') (105). 'Sleeping troubles' presented a Cronbach's alpha coefficient of  $\alpha = 0.85$  and was used in article 3 to test for potential confounding.

## **6.4 Data analysis**

Statistical analysis was conducted with SPSS Statistics 24. Data collected via SurveyXact was imported to SPSS, and variables were defined, i.e. named, characterized by type, decimals, values, missing and labelled. Data from the printed format of the questionnaire was then additionally entered directly into the file. Variables were checked for errors by means of descriptive statistics techniques, including frequency distributions and minimum and maximum values for all variables.

When summing up scores for the COPSOQ subscales missing values were replaced by individual subscale means in accordance with COPSOQ guidelines (105). Replacement of missing values was not relevant for the SOFI as all subscales were complete.

To be able to include interaction terms in the analyses, involved variables were first centered at the mean and then multiplied. This included the variables 'job demands' and 'job control' for paper 2 and 'work-family conflict' and 'support from nearest superior' for paper 3.

For both, article 2 and 3 descriptive analyses were conducted first, presenting continuous variables with means and standard deviations, and bivariate ones with frequencies/

percentages. To determine bivariate associations between fatigue scores and potentially associated variables Pearson correlations were used. In order to maximize power only factors associated with one of the fatigue dimension at a significance level below  $p = 0,05$  were included in the multivariable analyses.

As data came from individual employees nested within specific and different organizational units (terminals and ships) mixed effect null models were tested to examine if multilevel analyses were required. Due to the low intra-class coefficients found the main analyses were, however, based on multiple linear regression analyses.

Preliminary tests were run to check for potential violations of assumptions in terms of linearity, multivariate normality, homoscedasticity, multicollinearity and outliers. In this process between zero and seven outliers (standard residuals  $> 3$  standard deviations) were detected, and the identified cases were eliminated for the respective models.

For both, article 2 and 3, standard multiple hierarchical linear regression models were designed for the prediction of the five fatigue dimensions under study. To additionally test for a mediating effect of sleep satisfaction (article 2), another hierarchical model with the same covariates was run for predicting sleep satisfaction, after which sleep satisfaction was entered as a final predictor variable into all five regression models.

## **6.5 Ethics and data protection**

According to Danish law questionnaire surveys do not require approval by an ethical committee or informed consent (138). As personal data was included approval was obtained from The Danish Data Protection Agency (139).

## 7.0 Results

### 7.1 Paper 1: Review of determinants of fatigue in seafaring

A total of 19 out of 98 eligible studies were included in the systematic review, and the results of the review suggested a range of determinants for fatigue. However, methodological limitations in the existing literature (especially due to cross-sectional study designs, potential confounding, an exclusive focus on officers in the merchant marine in many studies, and small sample sizes as well as often low response rates), preclude final conclusions concerning the influence of these factors on seafarers' fatigue. Also, there was a wide variety in measurement of fatigue which additionally made comparisons between studies difficult. At the same time, most studies so far have focused on and provided evidence for more proximal determinants, particularly sleep quality and work times, indicating that there is a distinct lack of research on other types of determinants, such as the psychosocial work environment.

Specifically, out of the 19 studies reviewed for this research 8 considered *sleep-related factors*, and it was found that sleep, as expected, was consistently associated with fatigue. Thus, studies found that having poor sleep quality and being sleep deprived had an adverse effect on fatigue. Lacking sleep while at sea as compared to home was also found to be related to excessive sleepiness. *Work time-related factors* were the focus in 10 studies. These studies showed that working night shifts and standing watch during nights was experienced as more fatiguing compared to working day shifts and day and evening watches. Working in the 6h-on-6h-off watch system was also shown to be more fatiguing compared to the 4- on-8h-off-system, which was also the case for rotating shifts compared to fixed ones. Also, fatigue increased over watch/shift – a tendency that was also recognized for tour length.

Beyond sleep-related aspects and time of work (days/nights) the following factors have been investigated and were generally found to be positively associated with fatigue 1) long working hours, working overtime and high task demands, 2) high subjective disturbance in terms of noise, vibration and vessel motion, and 3) psycho-emotional strain, high job stress, lack of support and low job security. However, while findings were largely consistent, evidence is based on very few studies indicating that a definite conclusion is tentative at best.

In summary, although there were methodological limitations in the existing literature, the results of this review suggest that sleep- and work-time related factors are determining fatigue, and realistic countermeasures, e.g. in terms of shared night shifts, are recommended. More methodologically rigorous investigations of a greater range of factors, e.g. including psychosocial factors, and of the complex interactions between factors, however, are needed to support fully comprehensive future preventive programs.

## **7.2 Paper 2: Fatigue and its association with job demands and job control**

The second paper was based on data from a study aimed at examining the associations between fatigue in ferry ship employees and a) work stress levels in terms of physical work environment stressors, such as noise, vessel movement, vibration, heat and cold, and b) perceived job demands as well as job control. A further purpose of the study was to test c) whether a potential effect of work stress was mediated by sleep satisfaction. A positive relation between physical work stressors and fatigue was expected, while according to the Demand-Control model and supported by findings mainly from land-based occupational areas and one prior study from seafaring it was expected that higher perceived job demands and lower perceived job control would be associated with higher levels of fatigue. Further, and in particular, high demands combined with low control were assumed to be associated with higher levels of fatigue. Moreover, it was expected that effects from

job demands and job control would be attenuated once sleep satisfaction was entered into the models.

The study found that physical working environmental stressors were only associated with lack of energy. Further, main effects for perceived demands showed that more demands were positively related with all the psychological aspects of fatigue as well as with physical exhaustion, while effects for perceived control showed that more job control was related to lesser lack of energy, lack of motivation and sleepiness. In contrast, none of the findings for the interaction between job demands and job control indicated any significant effect, and so no support for the buffer hypothesis was provided.

After adjustment for sleep satisfaction prior associations between physical stressors, job demands as well as job control largely stayed significant but in all cases, were reduced in size, and in all cases, adding sleep satisfaction to the models significantly increased explained variance in the examined fatigue sub-dimensions.

### **7.3 Paper 3: Fatigue and its association with work-family conflict and supervisor support**

The third paper, based on the same study as paper 2, aimed at examining the association between fatigue and work stress levels in terms of a more specific work-related stress factor than general work demands which were examined in paper 2. Thus, the focus was a) on the role of work-family conflict and b) on the social resource factor 'support from nearest supervisor', while adjusting for the influence of job demands, sleeping troubles and other potentially confounding factors. Further, it was tested c) whether support from nearest supervisor moderates an effect of high levels of work-family-conflict on fatigue. In accordance with findings from studies conducted in other occupational areas than seafaring a positive relation between work-family conflict and fatigue was expected. Support from nearest superior on the other hand was expected to have a negative impact



on fatigue, and to have a moderating effect on the association between work-family conflict and fatigue.

In accordance with expectations, even after controlling for socio-demographic and work place characteristics as well as work demands and sleeping troubles, main effects for work-family conflict showed that more conflict was positively related with all aspects of fatigue, whereas more perceived support from nearest supervisor was associated with lesser lack of energy, physical exertion and lack of motivation. Associations with work-family conflict were generally found to be stronger than those for support.

In addition, tests for an interaction between work-family conflict and support from nearest superior indicated that support moderated the effect from high levels of conflict on physical exertion and physical discomfort while there was no indication for such an interaction on lack of energy, lack of motivation or sleepiness.

## **8.0 Discussion**

### **8.1 Main findings**

From the systematic review presented in this PhD (paper 1) consistent support is provided for an adverse effect on seafarers' fatigue from working night shifts and in the 6h-on-6h off watch system as well as for the relevance of poor sleep quality and sleep deprivation. The review also points out a need for studies investigating a wider range of factors and more complex interactions between factors as well as studies with lesser risk for methodological bias than prevalent in a large percentage of current literature. The second and the third article found support for an additive effect of perceived levels of physical and psychosocial work stressors and different dimensions of fatigue among Danish ferry crew members and those working in ferry terminals. Findings from the second article further suggested that associations were stronger for the psychosocial than for the physical work stressors and that sleep satisfaction was partly mediating this relationship. In the third article, it was outlined that work family conflict was strongly positively associated with fatigue while higher supervisor support tended to go along with lesser fatigue, however less consistently and less strongly than work-family conflict. This study also suggested that support from nearest superior can moderate the effect of work-family- conflict on physical exertion and physical discomfort.

### **8.2 General discussion of the findings**

#### Paper 1

The systematic review aimed to describe all possible determining factors of seafarers' fatigue from studies presenting quantitative data, and based on the 19 studies that were included it brought forward two important findings. First; though evidence was found to support a range of factors, most consistent and strong support was found for proximal and intuitively plausible factors, namely sleep- and worktime related factors. The evidence found in this review is in line with findings from prior, older reviews on stress and strain in

seafaring (30, 40, 140), as well as with findings from other lines of the transportation industry (74, 75, 81-83, 86, 141) and in different occupational sectors (70, 76, 79, 80). It is striking, though, that beyond this smaller range of issues other factors, particularly aspects related to the psychosocial environment have not yet been looked at in a seafaring context by a sufficiently large number of studies to allow for firm conclusions. Second, more than half of the included studies had to be considered as being at substantial risk of bias, e.g. due to nonsystematic attempts to control for confounding by study design and/or by statistical controls, thus jeopardizing internal validity. Further it could be questioned whether samples were representative for the seafaring population in general, e.g. because a substantial group of studies focused only on officers and/or watch keeping personnel from the merchant marine. Moreover, many samples were small and response rates often low. Yet another potentially problematic issue was that measurement in many studies was based on single items, raising questions of measurement validity. Therefore, and also because study types and particularly fatigue measures were very heterogeneous, the review was only able to come up with limited conclusions.

### Papers 2 and 3

#### *Levels of Fatigue*

Fatigue scores tended towards the lower end of the scales (paper 2 and 3). Thus, the highest mean score was found for lack of energy (M=2.0), and 18 % of the respondents reported a score of  $\geq 4$  indicating that only 18 % perceived higher levels of lack of energy. Physical exhaustion presented the lowest mean score (M=1.3), and here only 8 % of the respondents reported a score of  $\geq 4$  indicating that 8 % did perceive higher levels of physical exertion. Mean scores and percentages ( $\geq 4$ ) for physical discomfort, lack of motivation and sleepiness were M=1.5 (10 %), M=1.6 (11 %) and M=1.8 (14 %), respectively.

In general, these levels of reported fatigue seem low when compared to studies from other branches (71 % in road transportation (142), 75-90 % in aviation (55, 56) and 16-38 % in the general working population (50, 55, 56)), but also in comparison to other studies from a seafaring context (38-76 % (30, 53, 54)). At first glance, this may suggest that ferry shipping- at least in Denmark - is associated with less fatigue than other seafaring occupations. One explanation could be that in ferry shipping in Denmark more employees tend to return home at night compared to those working in the merchant fleet where some crew members can be away from home for months (28, 143). It is a well-established fact in maritime work, though, that working night shifts is more fatiguing compared to day- and evening shifts (137), and in the present study it was still about half of the study population who reported that they were engaged in habitual night work. This tends to be within the normal range in a seafaring context (54, 144, 145) and contradicts an explanation based on lower-demand levels alone. Also, prior studies have indicated that more frequent port calls actually are perceived as more fatiguing than longer, uninterrupted trips (28, 53, 146). Another or additional explanation is that the different fatigue levels may at least partly result from differences in assessment. Compared to other often-used single item instruments for fatigue measurement, SOFI offers a broader and more in-depth assessment of specific types of fatigue symptoms and thus allows for differentiation of specific types of work stress effects on fatigue. However, due to the retrospective nature of assessment this may come at the expense of precision, leading to underestimation when compared to one-dimensional, situational diary-type measures. Further, as SOFI is to be rated with regard to how respondents felt when they were most tired when at work during the last four weeks, it may fail to detect less vivid – but still essential – symptoms of fatigue, which could also lead to an underestimation compared to the situational diary-type measures.

In this vein, Leung et al. (144) in their study on high-speed maritime craft officers (about half of who worked night shifts) also used SOFI as assessment instrument and found low

levels of fatigue, while studies using situational, diary-type single-item instruments, such as the Karolinska scale, in general reported higher fatigue levels (28, 53, 147-149).

Beyond SOFI the present study also included two single item questions asking respondents to indicate if they had unintentionally fallen asleep while at work or if this had happened to any of their colleagues. In line with the discussion above it is interesting to note that 13 % of respondents reported that they had unintentionally fallen asleep while at work, while 24% reported that this had happened to one of their colleagues. These numbers somewhat stand out against the relatively low SOFI-scores. It can suggest that variation results if various symptoms, such as those adopted by SOFI, or a single symptom/consequence of fatigue, such as 'falling asleep' are being assessed (150) as fatigue measurement may hinge upon the interpretation of words by respondents (47), or, as with any other symptom, such as pain, depend upon the interpretation of fatigue-related signs, such as palpitations, feeling uninterested and feeling sleepy (2, 47, 58, 61, 69, 151). This suggests that context, social norms and individual predisposition should be considered when interpreting – and not least – comparing results (47, 58). This discussion generally raises the question on how fatigue is best measured – for instance by single item- or by a battery of symptoms. A selection of valid and reliable fatigue measures exists (58, 61, 152), but given the complexity and the definitional difficulties with fatigue, a gold standard is absent, and therefore an answer to that question it not obvious. In fact, it could be argued that fatigue measures are best chosen/tailored to the situation – at the expense of generalizability - or else – where possible – several measures of a different type may be combined (58). In any case, comparisons across different measures of fatigue may be problematic.

#### *Bivariate associations between fatigue and socio-demographic and work characteristics*

In accordance with prior evidence (23, 47, 153, 154) female respondents were found to report more fatigue, i.e. physical discomfort than males (paper 2 and 3).

As for workplace (paper 2 and 3), those working in the terminals were found to perceive more fatigue (higher physical discomfort and sleepiness scores) compared to their seafaring colleagues. This might seem counterintuitive as working on board of ferries seems to indicate exposure to a greater number of fatigue-related risk factors such as physical work stressors (e.g. engine noise) or night work (137). However, those working in the terminals also work late evenings, they are exposed to physical work stressors (e.g. noise from idling ship engines) as well as work tasks, such as loading/unloading cars and luggage to/from the ferry ships and they must comply with timetables and accomplish all tasks needed to uphold timely departures, which are all potential risk factors for fatigue (1, 43, 44, 46, 137).

Also, interestingly, officers were found to perceive less fatigue (lower physical discomfort and sleepiness scores) than non-officers (paper 2 and 3). Non-officers tend to engage in more manual labor compared to officers (155), a difference which is likely to manifest itself in more symptoms like stiff joints, muscle ache or rapid heartbeat. These findings agree with those of a study by Bridger et al. (155), who found that a high need for recovery after work was associated with high physical work demands in ratings. In contrast, however, Barnett et al. (28) reported higher levels of sleepiness at work among officers compared to ratings. These variations in findings could be due to different types of seafaring and respective work tasks involved, and moreover the inclusion of terminal workers in the present study may play a role. However, the issue of fatigue differences in different occupational groups may certainly warrant further, closer inspection.

Not surprisingly, those with habitual night work (paper 2 and 3), lower satisfaction with sleep (paper 2) and more sleeping troubles (paper 3) were found to report higher levels of fatigue. An adverse impact from these factors also has consistently been recognized in other studies in seafaring (28, 40, 137) as well as in other industries (1, 45, 74, 75, 86, 87, 156). It is notable, however, that as reported in the third article, typical time of work did

not predict fatigue, i.e. habitual night work did not have a significant impact on fatigue-levels in the final models, when sleep quality was controlled for. This may suggest that sleep quality-related factors, such as sleeping troubles, are more potent with respect to fatigue than is night work in ferry shipping per se (157, 158), even though night work has been found to be a potent predictor for the development of sleeping problems.

### *Multivariable associations*

The hypothesis that disturbance from the physical working environment and psychosocial work environmental factors, such as job demands, job conflict, work-family conflict and support from nearest superior may be associated with fatigue among ferry ship employees was based on the emergent evidence supporting such relations in on-shore settings (43, 44, 46, 49, 100-102, 114, 119, 125) as was described in chapter '4.2.2 Job demands, job control, support and fatigue' and '4.3 Psychosocial factors: work-family conflict'.

Consistent with prior findings, the results presented in this PhD supported that more general job demands and specifically a higher level of perceived work family conflict were related to more experience of fatigue, while the potential resources, i.e. job control and support from nearest superior went along with lesser fatigue (papers 2 and 3).

Other studies in a seafaring context, which have involved these factors, though very few in numbers, have similarly reported positive associations between time pressure, physical or psychological demands, work frustration and stress and strain, including fatigue symptoms among seafarers (28, 137, 145). Also, it has been reported in one prior study on seafarers working onboard supply vessels for the oil and gas supply industry that seafarers experiencing higher levels of job control also reported lesser fatigue (145), hereby suggesting that psychosocial factors are linked to fatigue in ferry shipping as well as in other segments of maritime work. In contrast, this PhD is the first to investigate the association between work-family conflict and support and fatigue in a seafaring context (paper 3). Effects – especially from work-family conflict – were found to be strong, thus

indicating that work family conflict and support from nearest superiors may be important contributors to fatigue among ferry ship employees. Though a direct comparison is not possible, this is consistent with findings from a study by Oldenburg et al. (143), who identified separation from one's family as an important stressor onboard merchant and passenger vessels, as well as findings from other occupational branches than seafaring also have been found to suggest work-family conflict as an important stressor (see subchapter '4.2.2 Job demands, job control, support and fatigue' and '4.3 Psychosocial factors: work-family conflict').

Thus, these findings are generally in line with the Demand-control model, and in particular there is considerable evidence in support of the additive effects of its dimensions (13, 14, 98). One objection raised, though, is that past research often did not consider the simultaneous influence from other occupation-specific work factors (14, 108). Therefore, the present study added to the previous published findings in that the influence from physical work stressors was considered together with job demands and job control in the second article – and the associations of these factors with fatigue were found to be less strong than those with job demands and job control. This in line with a study by Oldenburg et al. (143) who found that psychosocial work demands and physical factors were important stressors onboard merchant and passenger ships. Also, Barnett et al. (28) reported psychosocial job demands and physical environmental issues as important contributors to seafarer's fatigue on board tankers, container ships and bulk carriers. Furthermore, and as discussed in the third article, the findings from this PhD suggest that work-family conflict is an important factor for ferry ship employees' fatigue, and that this factor is to be considered on equal terms with job demands, such as quantitative demands (159), especially in an industry where work conditions are likely to conflict with family life/responsibilities over time, such as is the case in ferry shipping and other maritime industries.



This study was the first to test the buffer hypothesis of the Demand-control model in a seafaring context. While the second article found no support for an interaction effect between job demands and job control, support from nearest superior was found to moderate the negative effect from perceived work-family conflict on two of the five dimensions of fatigue; i.e. physical exertion and physical discomfort. Evidence for a buffering effect of job control is generally conflicting (13, 14, 98), but for research on fatigue in particular it is notable that studies investigating the potential stress buffering effect from job control on fatigue or equivalent concepts, such as need for recovery tended to find no such effect (100, 160-164). This seems to be suggesting that job control may not be an adequate resource to moderate effects of job demands on occupational fatigue neither in ferry shipping nor in other industries. However, it has also been suggested that the reason for non-effects may be found in too unspecific measurement where there is a lack of match between demand and control dimensions (12, 14, 124). Therefore, the broader measures used in the present study may have prevented buffering to occur for the factor job control. In contrast, support from nearest supervisor was found to be an adequate resource to buffer the physical dimensions of fatigue – but not the more mental ones. Thus, the broader measures used in the present study may have prevented detecting such effects for the mental aspects of fatigue.

Beyond interactions between different psychosocial factors it would also be interesting to more closely investigate interactions and additive combinations between different types of fatigue-related risk factors in a seafaring context. Thus, a study by Wadsworth et al. (33) on 1855 seafarers working in the offshore oil support, short-sea and deep-sea shipping industries reported a dose-response relationship between the overall number of risk factors and a fatigue outcome measure (see paper 1). In light of these findings, combined effects of different types of factors – as with work-family conflict and support from nearest superior (paper 3) - on fatigue are likely to exist in a ferry shipping context, and studies investigating such relationships are needed to support future preventive programs (137).

As for sleep quality, it is notable that even though associations between sleep deprivation/poor sleep quality and higher levels of fatigue have been recognized in other types of seafaring than ferry shipping (paper 1) (28), this study is the first to investigate a potential mediating effect of satisfaction with sleep on fatigue in a maritime context (paper 2). Prior evidence in support of such a mediating effect from sleep-related factors has been found though for a variety of health-related outcomes other than fatigue and in other settings. For example, poor sleep quality has been reported to mediate the relationship between environmental factors, like noise, and hypertension in the general population (165), and in an occupational context sleep fragmentation has been found to mediate the relationship between social climate and conflict with co-workers and psychosomatic complaints among full time employees in health care, finance or management (166). Similarly, the present study found that effects of job demands and job control were – at least partly – mediated by perceived sleep quality (paper 2), that is higher job demands and lower job control were associated with less satisfaction with sleep, which again was strongly associated with higher levels of fatigue reports.

However, and as discussed in article 2, sleep satisfaction did not account for the whole association between job strain and fatigue suggesting the existence of other pathways, one of which may be linked to motivational processes (167-170). For instance, it has been proposed that workers in situations where job control is high are more motivated even when demands are high (167, 168) and decrease in task performance (speed and accuracy) due to fatigue has been found to be reversed as a consequence of increasing motivational levels after 2 hours of task performance (169). Moreover, work-motivation has been suggested as a mediating factor for effects of overtime on mental fatigue (170), and in relation to seafarers' fatigue (paper 1) (28) it seems relevant to investigate the role of motivation in the job stressor-fatigue relationship in greater detail.

## **8.3 Methodological considerations**

### **8.3.1 Strengths and limitations**

#### Paper 1

The systematic approach used in the literature review included a three-step search strategy, and a priori defined criteria for inclusion and exclusion allowed for a comprehensive review of the evidence on fatigue determining factors. The assessment of the methodological quality of the included studies was based on the Quality Assessment Tool for Observational Cohort and Cross-sectional Studies (171) and the Cochrane Collaboration's Tool for Assessing Risk of Bias (128) and allowed for an informed evaluation of the validity of the reviewed results, thus strengthening the validity and the conclusive power of the review. However, it cannot be excluded that the review overlooked studies not to be found in the publication outlets favored by the search strategy, and it might be argued that the exclusion of "grey literature" and possibly also of studies based on qualitative research designs to some extent limits the review's conclusion. However, initial database searches showed that studies providing qualitative data were extremely limited in number, and that results from fatigue-related research projects presented in reports or on webpages also seemed to be presented in published articles and/or conference papers - thus favoring the validity of the review's results.

#### Papers 2 and 3

The study was based on a clear theoretical rationale, i.e. the Demand-control model, which offers a solid theoretical framework for an investigation of the impacts of psychosocial job characteristics on workers' health and wellbeing, despite the points of criticism that have been raised regarding its hypotheses (12, 14). Further, research was guided by a coherent definition of fatigue, which provided a clear basis for the choice of measure, i.e. the Swedish Occupational Fatigue Inventory (SOFI), and formed a basis for an informed interpretation of results. Moreover, using SOFI, a well-validated tool, offered a comprehensive and more in-depth assessment of specific types of fatigue symptoms and

feelings. Thus, other than many other instruments used in this area of research, SOFI allows for differentiation of specific types of work stress effects on fatigue. However, due to its retrospective nature this may come at the expense of precision, leading to underestimation when compared to one-dimensional situational diary-type measures as discussed in the previous chapter 8.2 General discussion of the findings. The Copenhagen Psychosocial Questionnaire (COPSOQ) also is a well-validated and often used instrument which offers a comprehensive and thorough measure of the relevant factors in accordance with the Demand-control model, which has been adapted to a Danish context. In general, the questionnaire battery used to collect data on perceived fatigue, perceived physical- and psychosocial work environmental stressors was designed taking its starting point in the literature (paper 1). It included mostly standardized and validated measures (see above), and before its release it was tested in two prior piloting rounds by representatives from the ferry shipping industry and from the group of respondents.

The design of the study reported in paper 2 and 3 was cross-sectional, and respondents answered to a self-administered questionnaire. The study had originally been planned as a longitudinal survey with two points of measurement, but due to unforeseen events, e.g. one ferry ship was severely damaged while docked, another one went out of service for technical reasons and one of the shipping companies underwent reorganizations, this plan had to be changed and only one measurement point could be scheduled. Given the cross-sectional design the observed associations can therefore not be interpreted as cause-effect relationships, and causal ambiguity might further be created by the use of a self-report questionnaire since respondents with higher levels of perceived work-family conflict and less perceived support may have reported more fatigue or vice versa.

However, potential confounding was accounted for in terms of a wide range of factors, such as typical time of work (day and evening/day, evening and night), which have been recognized as important with respect to seafarers' fatigue (137). It cannot be excluded,

though, that other potential confounding factors were overlooked. For instance, long working days were not accounted for in the present study, despite the fact that this factor has been recognized as an important stressor on board merchant and passenger ships (143) and has been suggested as a potential determining factor for fatigue – as described in chapter '3.0 Determinants of fatigue: physical work environment, work organization and personal factors'. Neither was physical- or mental health taken into account. Seafarers must undergo regular medical examinations, though, based on which the physician estimates whether the physical and mental health of the individual seafarer is generally in a state permitting work on a ship (172). Thus, seafarers suffering from psychological disorders would have been evaluated as 'non-fit' for work, and it would therefore not have been likely they were part of the study population. Terminal workers are not routinely screened, however, and therefore presence of psychological disorders among this part of the sample cannot be excluded.

Only Danish-flagged ferry ships were invited for participation the study in order to enable comparable working conditions across services. Within these limits, convenience sampling was used to recruit the ferry ship companies. More Danish ferry shipping companies were invited to the study than the two which actually participated, but 3 companies turned down the invitation due to cut- backs or reorganizational issues, and of the two participating companies, one enrolled only one of their services into the study also due to issues of reorganization. Therefore, it cannot be excluded that study findings might be biased as the fatigue profile and/or working environment might differ compared to that of other companies or other services. The response rate for individual participants was 38 % and thus rather modest. This is not uncommon in a seafaring context (137) as well as it is within the boundaries of what is typically achieved in organizational research (173). Nevertheless, it might suggest the possibility of selection effects and thus potentially biased results. In particular, the sample may not be fully representative of the population, which raises questions with regard to the external validity of the study. Even though

common in seafaring- and organizational research, a response rate of 38 % may be considered to be towards the lower end when considering the fact that the study had support from the management level in both participating companies. Comparison of study participants and the total of employees did not show any differences in terms of gender, age, rank or working at a terminal versus on board of ferries. However, this does not exclude the possibility that there may have been differential response rates depending on fatigue or perception of work environment (17, 173).

One reason for the moderate response rate may have been the length of the questionnaire. During the pilot tests respondents had specifically been asked to comment on the questionnaire's length and all agreed it was not too long. Still, it cannot be excluded that fatigued employees and/or those with higher job demands/levels of work-family conflict may have been less likely to answer (17). Another explanation may be confidentiality. This issue was addressed in the study information material shared with eligible employees, and it emphasized that civil registration numbers - or any other personal ID - were not to be provided and all data would be handled confidentially. Yet it cannot be excluded that some did not trust this information and may have been afraid that they would be identifiable after all and thus may not have felt willing to report fatigue or criticism regarding their work environment. Both explanations would imply that those with more fatigue and more work-related stress were less likely to participate. On the other hand, though, it has been found that those with more concerns about a topic or who are more affected by problems usually are more likely to participate (17, 173). In the present case, this would mean that those with more fatigue and/or more concerns about their work environment may have been more likely to take part which would have counteracted the above-mentioned tendencies.

However, despite the limitations the support for the independent relevance of the psychosocial working environmental factors found in the present study is in accordance with a large body of research evidence (see paper 2 and 3 and subchapter '8.2 General discussion of the findings' for details) from various areas of occupational research, which gives reason to believe that these nevertheless are valid findings.

## **8.4 Recommendations for the ferry shipping industry**

The relatively low fatigue levels found in the present study may suggest that there is only limited need for fatigue-counteracting initiatives in the Danish ferry shipping industry. However, variations in fatigue levels may suggest that some subgroups actually require interventions, i.e. for instance females, those working in the terminals and non-officers. Further, in other studies fatigue has been found to increase over time of duty in different segments of the maritime industry, also in ferry shipping (28, 144, 155, 174, 175) – an aspect which was not investigated in the present study. Moreover, it cannot be excluded that employees with high fatigue levels are more likely to leave ferry shipping or if they develop manifest disease are more likely to be “screened out” by the mandatory health check-ups.

Also, even if fatigue levels are not critically high, fatigue can still endanger the safety of the employees and the passengers (30, 31, 33), which all supports the need for fatigue countering measures in the ferry shipping industry.

### Job demands and job control

Interventions aimed at decreasing job demands or increasing job control have been found to have psychosocial and health effects in onshore occupations (104, 176-178), and especially interventions in which increases in demands went along with increases in resources, such as support were found to have a positive impact on workers' health (177, 178). Interventions including initiatives promoting adequate numbers of personnel,

increased task variety, more teamwork, problem solving groups/committees, participatory ergonomic groups and more time to plan work have been associated with improvement in perceived job demands and in physical and mental health. As for job control, similar initiatives have been found to have a positive impact, emphasizing the interdependence among these factors (177-179). In addition, introduction of education workshops, gradual/partial retirement, and participation in workplace decision-making have been found to have a positive impact (177-179). In this vein, it should be noted, though, that some interventions aiming at increasing control by means of introducing more team work were found to actually increase demands (e.g. time pressure and perceived work-family conflict) resulting in a worsening of anxiety, depression and musculoskeletal disorders among health center employees, general practitioners and blue-collar workers (177). Furthermore, more flexibility in working arrangements, such as self-scheduling of shifts (e.g. by means of participating in duty roster planning), have been associated with lesser tiredness, longer sleep duration and better sleep quality and more alertness (180).

Thus, ferry shipping companies are encouraged to focus future fatigue-prevention initiatives around staffing adequacy (e.g. adding manpower during peak times), task variety (e.g. rotating schemes), flexibility in working arrangements (e.g. participation in duty roster planning) and participation in workplace decision making (e.g. in planning of demand-reducing and control-enforcing initiatives).

#### Work family conflict and supervisor support

Besides job demands (40, 137) it seems that in particular demands with a high potential to conflict with family life are potent stressors, as has been shown in studies conducted among onshore occupations (181, 182). Accordingly, employees who report more control over their work schedules also report lower work-family conflict (183-185), which emphasizes the importance of taking into account the interrelationships between the different types of fatigue determinants. Therefore, the demands-reducing and control-



enforcing initiatives described above (e.g. staffing adequacy, flexibility in working arrangement and participation in workplace decision making) will also be of relevance in reducing experience of work-family conflict among ferry ship employees.

Also, higher levels of supervisor support – especially regarding work-family related issues – have been associated with lesser work-family conflict experience, which is also the case when the work organization as a whole is found to be supportive of family life (186, 187). Furthermore, leader-worker exchange, i.e. a process through which leaders and employees form a mutually influential and useful relationship has been found to have a positive impact on fatigue (121). Furthermore, training of leaders regarding strategies to demonstrate support for employees' personal and family lives, and training of leaders and workers in identifying practices and processes to increase employees' control over work-time have demonstrated to be effective in promoting positive changes in employees' perception of work demands and experience of work-family conflict (188). Hence, ferry ship companies are also encouraged to initiate leader training-programs with a profound focus on strategies on how to increase levels of employees' control over work-time, and on promotion of leader-worker exchange and work-family specific support in order to prevent or combat fatigue among their employees. It should be acknowledged, though, that increasing control levels over work time can be difficult in a regulated industry where tasks are subjected to strict timetables, like ferry shipping.

Regarding the nearest superior, leadership characterized as being supportive (leaders contribute with social support), considerate (leaders treat employees truthfully and with individual consideration) and transformative (leaders contribute with inspirational motivation, intellectual stimulation and treat employees with individual consideration) has been associated with positive health outcomes (123), whereas passive/non attentive leadership undermines employees' health and well-being (125, 189). Thus, the ferry

shipping companies are encouraged to stimulate leadership characterized by active support, consideration and transformation.

Furthermore, interventions including initiatives such as personnel adequacy, increased task variety, more teamwork, more time to plan work, problem solving groups/committees, participatory ergonomic groups and education workshops, have not only been found to increase subjective perceptions of job control but have also been found to improve the psychosocial environment in terms of more perceived supervisor support (177, 178). Hence, the demands-reducing and control-enforcing initiatives already described are seemingly also able to play an active role in increasing support from nearest supervisor in the ferry shipping industry.

Work-family conflict, as reflected in the strong main effects found (paper 3), is the most pressing issue to be tackled. However, it may not be possible to completely avoid such conflicts in a time-schedule regulated industry, such as ferry shipping, and supervisor support could be an important secondary intervention strategy to buffer the potential consequences of work-family conflict (10, 11) as suggested by the finding that high levels of support from nearest supervisor moderated the negative effect from work family conflict at least on certain aspects of fatigue.

In general, interventions that were specifically and directly targeted at improving health have been found to be more likely to have a positive effect on health compared to those that were driven by economic or managerial reasons (177, 180)

Therefore, the ferry shipping companies are encouraged to make health-promotion the driving source of future fatigue preventive programs. Furthermore, company macro-level initiatives, such as participation in workplace decision making (e.g. planning of, implementing and evaluation of training programs for supervisors on the company level)

are encouraged. Furthermore, in support of effective company micro-level initiatives, such as participating in duty roster planning at the terminal/ship level, it is also recommended to foster a macro-environment that is supportive of changes, and to combine demand-reducing (e.g. adding manpower in peaktime) and resource-promoting approaches (e.g. participating in duty roster planning).

### Sleep quality

Lack of sleep and poor sleep quality have been associated with risk of stress and strain among seafarers (40, 137) and in other occupational branches (1, 45, 74, 75, 86, 87, 141), and sleep is increasingly being found to be an important factor for human health and well-being (190-192). Further, evidence has shown that the psychosocial work environment is relevant for sleep (44, 117, 193). Thus, for instance, adverse influences from high levels of job demands and work family conflict, and lower levels of job control and supervisor support have been found on sleep quality (44, 193).

While in general psychosocial and health effects from workplace interventions have been studied (177, 178), the specific effects from such interventions on sleep-related factors have not received the same research attention and findings are inconsistent. Thus, one study found no indication of an effect on sleep disturbances or exhaustion from a participatory intervention where employees participated in a problem analysis and solution-finding process in a pre-school context (194), while another reported improvement in alertness- and sleep-quality scores among police officer's due to a transition from one shift system into another – and more flexible – system (195).

Thus, the evidence is indicating that there is a need for more research testing the impact of changes in the psychosocial work environment on sleep-related factors, such as which psychosocial work environment-related changes lead to sleep-related improvement for which occupational groups in different settings. However, the ferry ship companies are

also encouraged to consider specific sleep promoting initiatives, such as offering comfortable beds in cabins/rooms with little noise and shift-systems that support intra- (e.g. in terms of napping) and inter-shift (e.g. sufficient time between shifts) recovery (81, 196).

## 9.0 Conclusion and perspectives

The aim of this PhD was to investigate the link between fatigue and the work environment in Danish ferry shipping employees, and its results are based on a systematic description and analysis on what is already known about determinants of seafarers' fatigue and from an assessment on the quality of this evidence as well as on data on the association between different physical and psychosocial work environment stressors and different aspects of fatigue obtained from a cross-sectional observational questionnaire survey using standardized measures.

The existing literature generally supported a range of factors with an adverse effect on seafarers' fatigue. The review also suggested that many of the findings were prone to be biased due to potential confounding. Nevertheless, the review findings still established sleep- and work-time related factors as important determinants of seafarers' fatigue. Furthermore, it pointed to a pertinent need for studies of high methodological quality investigating a wider range of potential determinants, such as factors related to the psychosocial work environment, and the interplay between them, while at the same time including a wider range of occupational groups within seafaring than officers and watchstanders as well as employees from other segments than the merchant fleet.

Based on a questionnaire survey study this PhD further contributes with knowledge on psychosocial work environmental factors and their contribution to fatigue in a very specific workplace, i.e. ferry shipping, which constitutes a vital connection for the smaller Danish islands. One of the findings of the survey was the rather low level of fatigue among crew members and terminal workers. The Swedish Occupational Fatigue Inventory, which was used as fatigue measure in the survey, allowed a more in-depth assessment of different dimension of work-related fatigue and thus differentiation of specific types of work stress effects on fatigue. However, this may have come at the expense of precision compared to usage of repeated, diary-type single-item measures. Therefore, and because even lower

levels of fatigue may pose a potential threat to workers' health and wellbeing as well as to the safety of crew and passengers, managing fatigue in the ferry shipping industry may still be important. This also outlines the need for future studies comparing how different types of fatigue measures may affect results. As the survey findings indicated heterogeneity in fatigue-profiles across gender, occupational groups and work places it is important that future fatigue prevention programs are customized to each group, and that future studies in the field investigate fatigue-profiles in the ferry shipping – maritime – industry in greater detail to support such future programs.

As for the influence from the psychosocial work environment the factors job demands, job control, work family conflict and support from nearest superior were all established as potential risk factors of fatigue, particularly regarding mental aspects of fatigue. In addition, sleeping troubles were identified as being associated with fatigue, and satisfaction with sleep was found to mediate the effect from job demands and job control for all sub-dimensions of fatigue. Thus, it is recommended that future prevention programs are centered primarily around demand- and work-family conflict reducing initiatives, but also include control- and support promoting interventions, and possibly also taking into account sleep promoting measures based on improvements of the sleeping environment on board.

However, to be able to make more specific recommendations about the design of intervention measures more studies are needed to establish a clearer picture of the causal relationship between these factors and work-related fatigue among ferry shipping employees. In particular, from an intervention perspective it may be required to further specify measures of work demands, control, work-family conflict and supervisor support to identify sub-dimensions to be targeted for change and to also gain more information on the interplay and possible moderating mechanisms among stress factors and resources.

Such knowledge should be provided from studies which attempt to establish clear causality and exclude potential confounding influences by using more methodologically compelling designs and/or make systematic attempts to assess and statistically control for such factors. It needs to be acknowledged, though, that ferry shipping - seafaring in general - is a challenging field for research as the seafaring group of employees and their workplaces are - literally - moving, and the very time pressure which makes this a potentially stressful occupation and accordingly an important field for health-promoting interventions might also act as a barrier when it comes to participation in research projects. Doing research within such a context may be thus more logistically challenging and require more resources than 'normal' land based occupations.

Despite these challenges, it needs to be kept in mind that even though observational studies can be an important first step in establishing knowledge, and this PhD has provided support for the relevance of factors such as job demands, job control, work family conflict and support from nearest superior as potential preventive agents against fatigue, only future intervention studies can reveal whether changing these factors in the ferry shipping industry will in fact have a positive impact on fatigue among its employees.

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## **Appendix 1: Rules and regulations in Denmark**

In Denmark, the work environment is regulated by the Work Environment Act (Arbejds miljøloven). This act is administered by the Danish Working Environment Authority (Arbejdstilsynet), and it contains the rules that apply for the working environment, among others that 'work should be performed in a safe and healthy manner'. The Working Environment Act is mandated by law, and therefore it can lead to penalties if the rules are violated. However, it should be noted that the Work Environment Act does only apply to shipping and fishing with regards to 1) loading and unloading of ships, including fishing vessels, and 2) shipyard work on board ships, or work that can be equated with shipyard work. Apart from that only Danish land-based occupations are covered by the Act (197).

However, the Danish Maritime Authority (Søfartsstyrelsen), a government agency under the Danish Ministry of Commerce (Erhvervsministeriet), has the responsibility for seafarers' employment, health and conditions of social security, and is governed by a collection of sea-related laws. Of these the Act on Manning of Ships (Bekendtgørelse af lov om skibes besætning), the Act on Seafarers Employment (Bekendtgørelse af lov om søfarendes ansættelsesforhold), the Act of Hours of Rest for Seafarers (Bekendtgørelse om søfarendes hviletid) and the Act on Maritime Safety (Bekendtgørelse af lov om sikkerhed til søs) are focal acts in terms of health and working environmental matters. According to the Act on Manning of Ships the Danish Maritime Authority, with respect to type of ship, its equipment etc., stipulates guidelines for crew size and composition on Danish (ferry) ships to support safe and healthy conditions on board. Thus, this act first and foremost influences health and safety by ensuring sufficient manning (198). According to the Act of Seafarers Employment only Danish citizens over the age of 16 can sign up for a voyage and that all Danish seafarers must undergo medical examinations every year (age 16-18) or every second year (above the age of 18) to uphold their discharge book. It also encompasses details on the service conditions, e.g. on employment contracts, resignations agreements and health services. Furthermore, according to this act 'seafarers are entitled

to regular rest hours that are long enough to foster good health and safety' and that hours of rest must be in accordance with the rules in force (199). Regulations, specified in the Act of Hours of Rest for Seafarers, provide seafarers with at least 10 hours of rest a day, and at least 77 hours of rest a week. The time of rest can be divided into two periods, of which one must be of at least six hours, and there must be a maximum of 14 hours between two rest periods. If between the ages of 16-18, a seafarer is entitled to a rest period of at least 12 hours a day between 8pm and 6am, and at least 84 hours of rest a week. The time of rest for young seafarers can be divided into two periods of which one must be of at least eight hours and there must be a maximum of 12 hours between two rest periods. It should be noted that the hours of rest may be departed from for watch-keepers, for seafarers whose work include tasks related to safety and pollution prevention, for seafarers engaged on ships on short voyages, or in case of an emergency or the like. If these regulations are departed from seafarers must be compensated in terms of more frequent or longer periods of leave or by the granting of compensatory days off (200). The Act of Maritime Safety has the sole purpose of ensuring safe operations of seaborne carriages and it covers passages on ships construction. Vessels must be built, equipped and operated so that human life is protected. It also verifies that 'It is the duty of the ship-owner to ensure that the ship-master can fulfill his or her obligations' and 'it is the duty of the ship-master to ensure that the ship is in safe condition, and that seafarers are protected when working on board (201).

It should be noted that the Danish ferry shipping Industry is also covered by Act on Ferry Service (Bekendtgørelse af lov om færgefart) which has the sole purpose of ensuring an effective fulfillment of society's need for ferry services (202).

# Appendix 2: Flow diagram

Flow diagram illustrating the process of selection of articles and conference papers

