SHIFT YOUR WORK

Hardy van de Ven

Shift Your Work

Towards sustainable employability by implementing new shift systems

Colofon

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CHAPTER 1

General introduction

General introduction

A major challenge in the coming years is to help the ageing worker remain productive during its working life. This is particularly important for workers with taxing jobs, like shift workers. Shift work can be demanding due to disturbances of biological and social circadian rhythms (1-3), which have been suggested to become more demanding in older age (4). One of the suggested countermeasures to ameliorate the negative effects of shift work is to implement new shift systems (5), which brings us to the overall aim of this thesis: to contribute to a better understanding of sustainable employability of older (and younger) shift workers by implementing new shift systems.

This chapter first provides an overview of the background of shift work and its effects on important concepts related to sustainable employability like health, work functioning and social life. Next, two separate parts introduce the supporting premises of the overall aim of this thesis. Part I explores the ageing shift worker and challenges concerning sustainable employability. Part II presents the importance of the design of a shift system in facilitating sustainable employability, and, in particular, the process of successfully implementing a new shift system. This introduction concludes with the outline of this thesis.

Background of shift work

Shift work is used to provide 24/7 coverage of necessary services (e.g. police, fire brigade and healthcare), and, due to efficiency- and capacity-related reasons, to keep production processes running around the clock. The term 'shift work' is used to describe a variety of working time arrangements, like working outside regular working hours (i.e. 9:00 to 17:00 from Monday to Friday), or working at changing or rotating hours. In a more strict description, shift work refers to an arrangement in which workers alternate in a given work process to maintain continuity and productivity over the working day or week (6).

In 2013, 64% of the Dutch worker population sometimes or regularly worked outside regular working hours, about 50% worked evenings and weekends, and almost 17% night work (7, 8). From 2003 to 2013, the percentage of work outside regular working hours has increased by 8% (7). This increase is mainly due to an increasing number of workers reporting evening and weekend work, while the percentage of night work has remained similar to previous years (7). Using the strict description of shift work, approximately 17% of the Dutch workforce sometimes or regularly worked in shifts in 2013 (8). An increase of almost 3% compared to 2006 (8, 9).

The way shift work is arranged depends on the shift system. Sallinen and Kecklund have divided shift systems into five broad categories: regular 3-shift systems; irregular 3-shift systems; 2-shift systems; permanent morning, evening or night work; shift systems during extended operations (10). Workers may only work in one of the available shifts (permanent morning, evening or night shift), or rotate between the different shifts (2- or 3-shift systems). Regular shift systems are cyclic with set start and end times, whereas in irregular shift systems these circumstances vary. While regular shift systems tend to be collective (i.e. one schedule fits all), irregular shift systems are often more individualized. Shift systems during extended operations are a collection of extreme shift systems, e.g. long shift duration (≥ 12 hours) in combination with long working hours (≥ 48 hours per week) and/or on-call arrangements.

The choice as to use a shift system mainly depends on the demand for personnel over time in relation to the composition of the workforce, i.e. how many workers with which capabilities are needed and available at a given point in time. Regular 2- and 3-shift systems are common in industry, where constant and stable production processes in combination with a homogenous workforce allow a regular shift system. Most often, in regular shift systems, teams are formed, ranging from two to three teams for semi-continuous production processes and four or more teams for full-continuous production processes. Irregular shift systems are frequently used in the transport sector and in public services. Especially long haul truck drivers have very irregular schedules in terms of varying start and end times, shift length and rest periods in between. For many public services, demand for personnel is lower during nights and weekends, and part-time work is widespread. Extended operations can be found on oil rigs and in the mining industry, where workers are far away from home. On-call work is common when 24/7 coverage is provided, without the necessity for an actual presence of a professional outside regular working hours.

Shift work and the circadian clock

Usually, work is performed during the day, nights are meant for sleep and social life is organized in between. The driving force behind this day/night rhythm are the biological circadian clock, and its derived version, the social circadian clock. The function of the biological circadian clock is to regulate body processes. When not disturbed by time cues, the biological circadian clock has a rhythm of approximately 24 hours (circa means about and dies means day) and it needs to be reset each day to align with the external environment. For humans the main external time cue is sunlight (11, 12). The social circadian clock is derived from the biological circadian clock, in the sense that the biological circadian clock promotes activity during the day. As most people have a normal daytime job (i.e. 9:00 to 17:00 from Monday to Friday), most social activities take place during evenings and weekends. Shift work interferes with both the biological and the social circadian clock by requesting to work during hours meant for sleep or social activities, and has been linked with adverse effects on health, performance and social life.

Shift work and health

The detrimental health effects of shift work are well documented and include an increased risk of developing sleep problems, cardiovascular diseases, gastrointestinal diseases, metabolic syndrome, diabetes and even cancer (1, 3, 13). Although the underlying mechanisms are not clear yet, several, often interrelated, pathways have been proposed, and range from disturbances in the sleep/wake cycle and desynchronization of the biological circadian clock to stress reactions and changed lifestyle behaviours.

Disturbances in the sleep/wake cycle is the most reported problem by shift workers, with approximately three quarters of shift workers reporting sleep problems (14). The biological circadian clock opens a sleep window and, in conjunction with the accumulated sleep pressure (i.e. time being awake plus accumulated sleep loss of preceding days), regulates falling asleep and waking up (15). Shift work, especially early morning work and night work, interferes with this mechanism by prolonging being awake, waking up before our internal clock tells us to and trying to sleep outside the predetermined sleep-window. In the short term, effects of interference of the sleep/wake cycle are shortened sleep length and decreased sleep quality (2, 3). In the long term, sleep problems and insufficient recovery have prospectively been associated with health complaints and sickness absence (16-18). Although researchers are still trying to find an answer to why we need sleep, several hypotheses have been posed. Sleep is probably needed to restore energy resources in the body, to recover from infections while at the same time boosting the immune system's resistance, and the restoration of synaptic homeostasis (19).

Repeated desynchronization of the biological circadian clock, i.e. the internal clock is not aligned with the external clock, is linked with an increased risk of developing chronic diseases. The biological circadian clock is controlled by the suprachiasmatic nucleus located in the hypothalamus, which acts as master clock (20). The master clock coordinates body clocks up to the cellular and molecular level to make sure they are properly aligned. In case of desynchronization, the master clock loses control over subordinate clocks, resulting in body processes not performing optimally. For example, diurnal secretion of hormones is surppressed and cell proliferation is affected (21), which both have been linked with an increased risk of developing cancer (22).

Next to repeated desynchronization, shift work might induce psychosocial stress and changes in lifestyle behaviour. Lack of control over working hours, increased work-family interference and insufficient recovery might contribute to increased stress (23). Stress is a well-known risk factor for all kinds of chronic diseases (24-26). Besides stress, shift work might impact health behaviour. Shift work might contribute to an adverse risk profile for chronic disease, which is illustrated by shift work being associated with smoking, physical inactivity and poor diets, and moreover with obesity (27, 28). Healthy food might be difficult to obtain or high energy food is used to counteract fatigue, while at the same time digestion is less efficient during nights and opportunities to engage in physical activities are limited (5, 22).

Shift work, performance and safety

Shift work has been associated with increased risk of sleepiness and decreased alertness, and may lead, by inference, to adverse effects on performance and safety (29). The main driver is the interference of shift work with the biological circadian clock and, more specifically, with the sleep/wake rhythm.

Shift work interferes with the sleep/wake cycle by postponing sleep and requiring to work and to sleep at a time in conflict with the circadian time (15), which might lead to acute sleep deprivation and chronic sleep restriction (30, 31). Extended periods of being awake lead to acute sleep deprivation. Without sufficient time to recover, sleep debt accumulates over the working week, leading to chronic sleep restriction (10, 32). Laboratory studies have shown that acute sleep deprivation, as well as chronic sleep restriction are related to a decrease of about 2 standard deviations in psychomotor performances and subjective alertness (31).

Due to complicated work processes, many different tasks, or work being performed as a team, it is difficult to assess individual work performance in the work setting (33). There is some evidence that work-based individual performance is optimal between 7:00h and 19:00h (34). More data is available about accidents. In an extensive review, Folkard and Tucker (34) have shown that the relative risk of accidents is largest during night shifts, in particular in the first few hours, followed by evening shifts. Furthermore, the relative risk increased with an increasing number of successive shifts, hours on the job and minutes after a break. Recently, shift work has been linked with a long-term decline in cognitive performance. Shift work experience exceeding ten years is associated with chronic impairment of cognition (35). Considering the effects of shift work on health, health-related functioning in work might also be affected by shift work.

Shift work and social life

Next to the biological circadian clock, shift work also interferes with the social circadian clock. Many family, social and leisure activities take place at fixed times, e.g. family dinner, holidays and sport events (36). Shift work interferes with these activities by demanding workers to work at times normally used for family and social life. Being unable to meet the demands of both work and family life might result in work-family conflict (37). Although work-family conflict is not directly linked to specific health complaints, higher levels of work-family conflict have been associated with increased levels of need for recovery, fatigue and risk of future sickness absence (38).

Part I: The ageing shift worker

The percentage of shift workers older than 55 years of has doubled in the period 2003-2013 to 17.4% (7). The increase in older shift workers may partly be explained by changes in demographics, and institutional and company regulations. The retirement age was increased to keep the social security system affordable. Today, older shift workers are also needed to compensate the increasing shortage on the labour market. At the same time, companies struggle to employ new (young) shift workers. The traditional strategy to place older shift workers in day work is therefore no longer feasible. Older shift workers are needed to keep 24h services available and production processes running around the clock. Hence, several challenges at the intersection of shift work and sustainable employability have to be addressed.

In this thesis, the operationalization of sustainable employability is inspired by the definition of Van der Klink et al. (39). Their definition includes prerequisites for sustainable and healthy functioning at work. Good sleep and sufficient recovery are among those prerequisites for sustainable employability of shift workers. Sleep quality and duration decrease up to the age of 45 years and remain relatively stable afterwards (40, 41). Concurrently, the physical and mental condition to recuperate deteriorates with age. Shift work tolerance, i.e. the ability to adapt to shift work without adverse consequences (42), has been suggested to be lower for older shift workers compared to their younger counterparts because of a decreased ability for circadian adjustment and a shortening of the circadian rhythm (43). A steeper decline of the work-ability index over age in shift workers compared to day workers has been presented as evidence supporting this suggestion (44).

As illustrated in the previous paragraph, research on sustainable employability in relation to shift work so far mainly focused on age. Yet, despite the detrimental effects of shift work and ageing, only a few differences have been found between shift and day workers regarding outcomes related to sustainable employability like sickness absence, early retirement and work disability (45-47). The strength and relevance of different individual and work-related predictors for work outcomes related to sustainable employability might differ. Furthermore, the authors of two reviews concluded that there was only a weak relation between age and shift work tolerance (40, 41). Individual differences in the timing of the biological clock (chronotype) seem to better explain individual differences in sleep duration and quality (48). Also the design of a shift system, rather than age, appears to be related to sustainable employability (49). Hence, in view of sustainable employability it is not only necessary to further examine shift work and age, but also to examine other factors next to age, such as chronotype, within the context of different shift systems.

Objective Part I: The overall objective of Part I is to examine the effects of shift work on health, work functioning and social life within different shift systems, with a special focus on age. The following three sub-objectives are addressed:
1. To examine which individual and work-related characteristics predict work outcomes related to sustainable employment among male shift and day workers.
2. To examine associations of chronotype and age with shift-specific assessments of sleep duration, sleep quality and need for recovery.
3. To examine need for recovery among technical distal on-call workers.

Part II: Towards interventions to enhance sustainable employmenability of shift workers

To actually help shift workers continue working in a sustainable and healthy way, interventions aiming to enhance sustainable employability of shift workers need to be developed and implemented. Several measures have been proposed to alleviate the burden experienced by shift workers (5). Bright light, melatonin, naps, use of stimulants and proper work scheduling have been suggested to support adaptation to shift work (5). Of those interventions, shift system interventions have been examined extensively, as the design of a shift system is a key determinant of shift work-related problems. Shift schedule characteristics like shift length, shift starting time, direction of rotation and the number of consecutive shifts or working days in relation to their distribution over the working week, can be considered when designing a shift schedule. In general, a fast (i.e. max 2-3 consecutive shifts) forward rotating (i.e. postponing the start time of consecutive shifts) schedule is favored to promote sleep (5, 10, 50), in particular for older workers (40). Still, there remain challenges to determine the relative and combined contributions of different shift schedule characteristics. There are also indications that increasing workers' control over working hours is beneficial for workers' health and well-being (51, 52). Whether these interventions will also improve health in the long-term, has yet to be proven (5).
The design of a shift system intervention is one step according to the latest scientific knowledge, the implementation process might be an equally important step for an intervention to be effective (53). Expert views on how to set-up an implementation process of a new shift system are available (54) and the attitude towards a new system may affect the results of an

effect-evaluation (55, 56). Yet, so far, neither the process prior to implementation, nor the attitudes of workers towards a shift system intervention, have been investigated systematically.

Objective Part II: The overall objective of Part II is to examine the relation between the design of a shift system and sustainable employability on the one hand and how to successfully implement a new shift system on the other. The following three sub-objectives are addressed:

1. To examine associations between ergonomic shift schedule criteria, separately and combined, for shift-specific and generic health and work functioning measures.
2. To examine facilitating and impeding factors for the implementation of a roster change.
3. To examine whether attitude towards a shift system implementation is prospectively associated with changes in health, work functioning and social life after implementation.

Outline

Part I comprises chapters 2 to 4 and focuses on the first objective, the examination of the effects of shift work on health, work functioning and social life in different settings. In **Chapter 2** we describe a prospective study among a large cohort of shift and day workers to examine whether health- and work-related characteristics assessed during periodic health checks are associated with outcomes related to sustainable employability. A sensitivity analysis was conducted to examine the effect of age on the results. In **Chapter 3** another concept besides age is explored. Associations for chronotype and age with shift-specific sleep and need for recovery are investigated among regular 3-shift workers. **Chapter 4** presents the associations of need for recovery with age, health and social life among distal technical on-call workers.

Part II consists of Chapters 5 to 7 and focuses on the second objective, the investigation of the design and implementations process of new shift systems. In **Chapter 5**, we examine associations between shift schedule characteristics, sleep, need for recovery, fatigue, health and work functioning among regular (semi-)continuous 3-shift workers of nine different companies. In **Chapter 6**, we study facilitating and impeding factors for the implementation of a new shift system. **Chapter 7** presents the investigation of the effects of workers' attitude towards a new shift system on changes in health, work functioning and social life.

Chapter 8 comprises the general discussion; we present the main results of the study and methodological considerations, and discuss implications for practice and research.

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CHAPTER 2

Individual and work-related predictors of work outcomes related to sustainable employment among male shift and day workers

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Abstract

Objectives The aim of this study was to examine which individual and work-related characteristics predict work outcomes related to sustainable employment among male shift and day workers.
Methods Between September 1, 2005 and December 31, 2009 data on individual and work-related characteristics of N=5640 employees of Tata Steel in the Netherlands were retrieved from the Occupational Health Service and company registers. Work outcomes related to sustainable employment were 1) temporarily being placed in less strenuous work, 2) sickness absence ≥6 weeks, and 3) leaving the organization. Cox proportional hazard analyses were performed for all outcome measures.
Results Similar predictors were found for shift and day workers, although some differences were observed. For shift workers, high blood pressure and cardiovascular disease were important predictors for sickness absence. For day workers, insomnia was an important predictor of sickness absence ≥6 weeks.
Conclusions Similar predictors in magnitude and direction were found for work outcomes related to sustainable employment among shift and day workers. Interventions aimed to enhance sustainable employability should focus on individual and work-related characteristics.

Introduction

In many developed countries the mean age of the general population is increasing (1). New policies and programs to prevent early exit of older workers from working life have to be developed (2). Therefore, a major challenge in the coming years is to help ageing worker populations stay at work in a healthy, productive and sustainable way. To facilitate sustainable employment, it is necessary to gain more insight into the characteristics that undermine sustainable employment (ie, those predicting work outcomes like long-term sickness absence or early exit from the labour market).

In the past few years, several studies have demonstrated that, in addition to individual characteristics (e.g. age, health status, work-family interference), work-related characteristics (e.g. physical and psychological work demands, decision latitude, job satisfaction) predict duration of sickness absence, turnover intentions, early retirement and work disability (3-10). However, these studies have been conducted in the general population. Policies and interventions might benefit from comparing worker populations, namely, shift and day workers.

Shift work can be burdening to workers due to the disturbance of biological and social circadian rhythms and is a well-known risk factor for health, safety and social well-being (11-13). Therefore, shift workers might be more at risk for sustainable employment, compared to day workers. Although no significant differences have been found between both groups with respect to work outcomes like sickness absence, early retirement and leaving the organization between both groups (14-16), it might be that the strength and relevance of determinants differ between shift and day workers. Kivimäki et al. examined the extent to which prevalent cardiovascular disease (CVD) and its risk factors (high blood pressure (HBP), high cholesterol concentration, obesity, and diabetes) are predictive of a person leaving the organization separately for shift and day workers (17). They found no difference between shift and day workers for these health-related risk factors associated with leaving the organization. However, to our knowledge, this is one of the few studies available, and it only focuses on health-related risk factors. Evidence about the relationship between individual and work-related factors on work outcomes related to sustainable employment is scarce among shift and day workers.

In order to understand and quantify the importance of different individual and work-related factors on sustainable employment among shift and day workers, the aim of the present study was to examine which individual and work-related characteristics predict work outcomes related to sustainable employment among male shift and day workers.

Methods

Study design

In this dynamic cohort study, prospective data of N=11,921 employees working at Tata Steel in the Netherlands were gathered between September 1, 2005 and December 31, 2009. Tata

Steel manufactures, processes and distributes steel products to worldwide customers. Data were retrieved from the Occupational Health Service and the company registers (18).

Study sample and procedure

Every three to four years, the Occupational Health Service of Tata Steel offers a health check to the employees by means of structured interviews. Data were used from the health checks conducted between September 1, 2005, and December 31, 2009. During the interview, a list of questions about individual and work-related characteristics was completed by the employees and checked by a company doctor (19). This information was taken as the individual baseline measurement of this study. If an employee had more than one health check during the 5-year study period, the first health check was taken as baseline.

Office workers (N=4,923) were excluded from this study, because their working conditions were not comparable with those of the shift workers and day workers in technical and maintenance jobs. Due to the small numbers of female workers, women (N=120) were excluded too. From a total of N=6,878 shift and day worker, N=1,238 (18.0%) shift and day workers were excluded from analyses, because no health check data were available. The final study sample comprised N=5,640 workers, divided into N=4,311 shift and N=1,329 day workers.

Measurements

Outcome measures

Work outcomes related to sustainable employment were operationalized by three dichotomous outcome variables (yes; no), 1) temporarily being placed in less strenuous work, 2) sickness absence of ≥6 weeks or 3) leaving the organization. The first occurrence of these work outcome was used for analyses. When these work outcomes did not occur, December 31, 2009 or the date participants left the organization was used as censoring date.

Tata Steel's Medical Department organizes special work accommodations in order to place personnel temporarily in less strenuous work. This is applied when employees have difficulties with work due to health complaints. Employees can be temporarily placed into day service (shift workers) and/or in an office job (shift and day workers). The first and last day of their temporary replacement were derived from the company's records.

Sickness absence was defined as being absent for ≥6 weeks and was based upon Dutch sickness absence legislation (Gatekeeper law) (20). After six weeks of absence a company doctor has to complete a problem analysis, including the reason for absence, the possibilities for recovery and the predicted time to return to work. The first and last date of a sickness absence episode were registered by the company. In this study no distinction was made between full and partial sickness absence.

Leaving the organisation was defined as the date an employee left the organization. The date of leaving the organization was derived from the company's registers. There was no information on the reason for leaving (e.g. retirement, death, resignation or a transition to another employer).

Individual and work-related characteristics

From the interview data, four individual (mental complaints, fatigue, musculoskeletal complaints and stiffness, work-related complaints) and eight work-related scales (psychological job demands, decision authority, skill discretion, perceived physical workload, physical exposure, job satisfaction, job security, and work organization and communication) were composed by summing the answers (yes=1 or no=0). The scales were constructed by means of a principal component analysis, reliability analysis and a face validity check. Furthermore, nine individual (sleep complaints, insomnia, HBP, CVD, gastrointestinal complaints, bronchitis, smoking, alcohol, work family interference) and two work-related (relation with supervisor, relation with co-workers) single items were included. All single items could be answered yes (=1) or no (=0). Age and gender were also registered during the health interview. In appendix 2.A the scales and items are described in detail.

The function level was deducted from the company registers. For each calendar year the function and a corresponding function level number were registered by the company. A high function level number implied more line management tasks, whereas a low function level number involved more operational tasks. The year of the health check was matched with the function description of that year and reflected the function level at baseline.

On September 1, 2005, three types of shift work schedules were present: a 2-shift schedule (no nights, no weekends), a 3-shift schedule (no weekends) and a slowly backwards rotating 5-shift schedule. This latter schedule involved three night shifts, two days off, three evening shift, two days off, three morning shifts and two days off (NNNxxEEExxMMMxx). All shift schedules included 8 hour shifts, morning shifts starting at 6:00, evening shifts at 14:00 and night shifts at 22:00. On September 1, 2006, a new 5-shift schedule was implemented, which involved a change for all 5-shift workers towards a fast forward rotating schedule (MMEExNNxxx). The analyses were adjusted for the different shift work schedules; shift workers were classified according to their work schedule into three categories: 2- and 3-shift workers, 5-shift workers without a roster change and 5-shift workers with a roster change.

Statistical analysis

Stratified Cox proportional hazard regression analyses were used to estimate hazard ratios (HR) and their 95% confidence intervals (95% CI) for shift and day workers for the relation between all independent variables and the three outcome variables in a prediction model, using method enter. Separate models were used for the three outcome measures. All models were controlled for age. The time interval used for the analyses was days. All analyses were performed using SPSS version 18.0.3 (IBM Corp, Armonk, NY, USA). An alpha of 0.05 was used in all statistical tests.

Two sensitivity analyses were conducted. The first sensitivity analysis was used to examine age-related effects, by dividing shift and day workers in two age groups: < 45 and ≥45 years. For the second sensitivity analysis, the influence of participants ending up in more than one outcome measure was examined by limiting the analyses to participants ending up in one

or none of the outcome measures.
Included and excluded workers were compared separately for shift and day workers. Due to the dynamic nature of this study, September 1, 2005, was defined as baseline for the comparison between included and excluded workers. At baseline an independent t-test was used to compare the age of included and excluded workers. Cox proportional hazard analyses were used to estimate HR and their 95% CI between included (=0) and excluded (=1) workers and their relation with the three outcome measures.

Results

Comparison included vs. excluded

The excluded shift workers and day workers for whom no health check data were available (N=1238) were on average 1 year and 6 years younger compared to the study sample. For both shift and day workers, excluded workers were more prone to be temporarily placed in less strenuous work and to leave the organization compared to the study sample. No differences were found between the excluded and included workers for the outcome sickness absence ≥6 weeks.

Baseline demographics

The total study sample comprised N=5640 workers, divided into N=4311 shift and N=1329 day workers (Table 2.1). Shift workers were slightly younger than day workers. During the study period, 12.6% of the shift workers and 10.6% of the day workers were temporarily placed in less strenuous work, 13.6% of the shift workers and 18.3% of the day workers were absent for ≥6 weeks and 5.1% of the shift workers and 5.4% of the day workers left the organization. For shift workers, the mean follow-up time for temporarily being placed in less strenuous work was 967 days (median 1008, SD 435), for sickness absence ≥6 weeks 968 days (median 1036, SD 434) and for leaving the organization 1062 days (median 1126, SD 386). For day workers, the respective numbers were 1028 days (median 1092, SD 424), 982 days (median 1065, SD 439), and 1107 days (median 1092, SD 371). Results for the three outcome measures are given in Table 2.2.

Temporarily placed in less strenuous work

Higher perceived physical workload was an indicator of increased risk of temporarily being placed in less strenuous work for both shift (HR 1.06, 95% CI 1.00-1.12) and day workers (HR 1.13, 95% CI 1.03-1.24). For shift workers, having bronchitis (HR 1.56, 1.17-2.09) and more physical exposure (HR 1.03, 95% CI 1.01-1.57) indicated an increased risk of temporarily being placed in less strenuous work, whereas a high function level indicated a reduced risk (HR 0.56, 95% CI 0.39-0.78). For day workers, more work-related complaints indicated an increased risk (HR 1.39, 95% CI 1.12-1.73) of temporarily being placed in less strenuous work.

Table 2.1 Demographics of the study sample (Shift workers N=4311, Day workers N=1329)

	Shift workers					Day workers				
	N	%	Mean	Min-Max	Median	N	%	Mean	Min-Max	Median
Outcome measures										
Less strenuous work	544	12.6				141	10.6			
Sickness absence ≥6 weeks	585	13.6				243	18.3			
Leaving the organization	219	5.1				72	5.4			
Individual characteristics										
Schedule										
2/3 shift worker	1616	37.5								
5 shift workers without a roster change	228	5.3								
5 shift workers with a roster change	2467	57.2								
Socio demographic characteristics										
Age			44.47	18-63	45.00			45.72	18-61	47
Health status										
Mental complaints			0.38	0-4	0.0			0.41	0-4	0.0
Fatigue			0.41	0-2	0.0			0.39	0-2	0.0
Musculoskeletal pain and stiffness			0.99	0-5	1.0			1.10	0-5	1.0
Work-related complaints			0.43	0-2	0.0			0.48	0-2	0.0
Sleep complaints	943	21.7				170	12.8			
Insomnia	259	6.0				65	4.9			
High blood pressure	451	10.5				159	12.0			
Cardiovascular disease	235	5.5				78	5.9			
Gastrointestinal complaints	310	7.2				86	6.5			
Bronchitis	245	5.7				92	6.9			
Lifestyle										
Smoking (yes)	1741	40.4				372	28.0			
Alcohol use (yes)	3528	81.8				1155	86.9			
Work family interference										
Work family interference	1528	35.4				130	9.8			

Table 2.1 (continued) Demographics of the study sample (Shift workers N=4311, Day workers N=1329)

	Shift workers					Day workers				
	N	%	Mean	Min-Max	Median	N	%	Mean	Min-Max	Median
Work characteristics										
Function level										
Function level (High)	572	13.3				327	24.6			
Psychosocial job demands										
Psychological job demands			0.67	0-3	1.0			0.91	0-3	1.0
Decision authority			1.93	0-3	2.0			2.77	0-3	3.0
Skill discretion			1.73	0-2	2.0			1.71	0-2	2.0
Good relation with supervisor	3522	81.7				1053	79.2			
Good relation with co-workers	3879	90.0				1203	90.5			
Physical job demands										
Perceived physical workload			0.96	0-7	0.0			1.35	7.0	0.0
Physical exposure			4.28	0-13	3.0			3.82	0-13	2.0
Other										
Job satisfaction			2.63	0-3	3.0			2.62	0-3	3.0
Job security			1.84	0-2	2.0			1.79	0-2	2.0
Work organization and communication			2.66	0-3	3.0			2.49	0-2	2.0

Sickness absence ≥6 weeks

Being a smoker indicated an increased risk for sickness absence ≥6 weeks for both shift (HR 1.23, 95% CI 1.04-1.45) and day workers (HR 1.45, 95% CI 1.10-1.92). Among shift workers, higher scores on fatigue (HR 1.15, 95% CI 1.02-1.30) and musculoskeletal pain and stiffness (HR 1.08, 95% CI 1.00-1.15), and having high blood pressure (HR 1.37, 95% CI 1.09-1.71) and cardiovascular disease (HR 1.67, 95% CI 1.28-2.19) indicated an increased risk for sickness absence ≥6 weeks, while a high function level (HR 0.56, 95% CI 0.41-0.77) indicated a reduced risk. For day workers, higher scores on mental complaints (HR 1.30, 95% CI 1.11-1.51) and having insomnia (HR 2.48, 95% CI 1.47-4.21) indicated an increased risk for sickness absence ≥6 weeks, while sleep complaints (HR 0.58, 95% CI 0.37-0.91) and job satisfaction (HR 0.85, 95% CI 0.72-1.00) indicated a reduced risk.

Leaving the organization

Shift workers with higher scores on mental complaints (HR 1.22, 95% CI 1.03-1.43) and perceived physical workload (HR 1.09, 95% CI 1.00-1.19), and having sleep complaints were at increased risk of leaving the organization, while lower scores on musculoskeletal pain and stiffness (HR 0.88, 95% CI 0.77-0.99) and psychological job demands (HR 0.83, 95% CI 0.69-1.00) indicated a reduced risk. For day workers, higher scores on fatigue (HR

1.64, 1.13-2.39) indicated an increased risk for leaving the organization and job satisfaction a reduced risk (HR 0.72, 95% CI 0.55-0.95).

Sensitivity analyses

The sensitivity analysis for age groups showed that older shift workers with good supervisor relations were at increased risk of being temporarily being placed in less strenuous work, while an opposite effect was found for younger workers (≥45 years: HR 1.21, 95% CI 0.88–1.67 versus <45 years HR 0.60, 95% CI 0.41–0.87). Furthermore, older shift workers with HBP were at decreased risk of sickness absence ≥6 weeks, compared to younger shift workers (≥45 years: HR 1.08, 95% CI 0.84–1.40 versus <45 years: HR 4.36, 95% CI 2.84–6.70). Older day workers with higher scores on mental complaints were at decreased risk of sickness absence ≥6 weeks, compared to younger day workers (≥45 years: HR 1.20, 95% CI 1.01–1.43 versus <45 years: HR 2.13, 95% CI 1.51–3.02).

The sensitivity analysis limited to participants ending up in one or none of the outcome measures revealed no major differences compared to the analysis including all participants with complete data.

Discussion and conclusion

This study examined individual and work-related characteristics for work outcomes related to sustainable employment among male shift and day workers. Slightly more shift workers were temporarily placed in less strenuous work, more day workers were absent ≥6 weeks and an equal amount of shift and day workers left the organization. Most of the predictors were similar in magnitude and direction for shift and day workers, although some differences were observed. These differences pertained to CVD, HBP and sleep.

CVD and HBP have been found to predict sickness absence ≥6 weeks only for shift workers. Shift work has been indicated as a risk factor of CVD, although evidence of a causal link is still limited (21-24). At baseline a slightly higher percentage of day workers reported CVD and HBP, which might indicate a CVD induced selection effect. However, Kivimäki and colleagues concluded in a study with a similar research design and a mainly female population that selection out of work due to CVD is not a major bias in shift work research (17). In line with the findings of Kivimäki et al, this study of a male population found no evidence of an increased risk of leaving the organization due to CVD or HBP for shift compared to day workers. In congruence with other studies, smoking was more prevalent at baseline among shift workers compared to day workers (21, 22), which might be one of the explaining factors for an increased risk of HBP and CVD among shift workers.

Insomnia has been found to predict sickness absence ≥6 weeks only for day workers. Although this finding is in line with earlier research associating poor sleep with sickness absence (25-29), other findings are contradictory. For day workers, sleep complaints protected against sickness absence ≥6 weeks. For shift workers, insomnia and sleep complaints did not predict sickness absence ≥6 weeks, while sleep problems are one of the most reported prob-

Table 2.2. Predictors of sustainable employment for shift and day workers (HR=Hazard Ratio, 95% CI=95% Confidence interval)

	Temporarily placed in less strenuous work				Sickness absence ≥6 weeks				Leaving the organization			
	Shift work		Day work		Shift work		Day work		Shift work		Day work	
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI
Schedule												
5-shift worker without roster change												
5-shift worker with roster change	1,23	1.03-1.48			1.23	1.03-1.48			0,67	0.49-0.92		
2/3-shift worker	1,04	0.70-1.55			1.04	0.70-1.55			0,59	0.31-1.12		
Individual characteristics												
Health status												
Mental complaints	1.07	0.96-1.19	1.17	0.95-1.43	1.09	0.99-1.19	1.30	1.11-1.51	1.22	1.03-1.43	0.79	0.57-1.11
Fatigue	1.02	0.90-1.17	0.91	0.69-1.21	1.15	1.02-1.30	1.17	0.94-1.45	0.95	0.77-1.17	1.64	1.13-2.39
Musculoskeletal pain and stiffness	1.05	0.97-1.13	1.05	0.91-1.22	1.08	1.00-1.15	0.99	0.88-1.11	0.88	0.77-0.99	1.00	0.80-1.25
Work-related complaints	1.10	0.98-1.23	1.39	1.12-1.73	1.06	0.95-1.18	1.08	0.91-1.28	0.96	0.80-1.16	0.90	0.63-1.27
Sleep complaints	1.21	0.96-1.51	1.04	0.62-1.73	1.09	0.88-1.35	0.58	0.37-0.91	1.60	1.15-2.23	1.34	0.67-2.69
Insomnia	1.11	0.81-1.52	1.09	0.53-2.22	1.29	0.98-1.72	2.48	1.47-4.21	0.84	0.51-1.37	0.93	0.28-3.09
High blood pressure	1.11	0.86-1.44	1.09	0.64-1.86	1.37	1.09-1.71	0.79	0.54-1.16	0.94	0.63-1.40	0.66	0.31-1.41
Cardiovascular disease	1.10	0.79-1.55	1.03	0.50-2.13	1.67	1.28-2.19	1.10	0.67-1.81	1.43	0.91-2.25	1.21	0.49-3.02
Gastrointestinal complaints	1.01	0.75-1.36	1.14	0.63-2.06	1.10	0.84-1.44	0.87	0.53-1.42	0.87	0.54-1.43	0.85	0.33-2.19
Bronchitis	1.56	1.17-2.09	1.64	0.96-2.80	1.02	0.74-1.40	1.30	0.83-2.02	1.05	0.61-1.81	0.76	0.27-2.15
Lifestyle												
Smoking	1.13	0.95-1.34	1.04	0.72-1.52	1.23	1.04-1.45	1.45	1.10-1.92	1.17	0.89-1.55	0.89	0.51-1.54
Alcohol	0.82	0.67-1.00	0.81	0.51-1.26	0.89	0.73-1.08	0.75	0.54-1.05	1.01	0.72-1.42	1.49	0.67-3.32
Work family interference												
Work family interference	0.89	0.74-1.08	0.96	0.56-1.66	1.03	0.86-1.23	0.69	0.42-1.14	1.05	0.78-1.41	1.06	0.44-2.53

	Temporarily placed in less strenuous work				**Sickness absence ≥6 weeks**				**Leaving the organization**			
	Shift work		Day work		Shift work		Day work		Shift work		Day work	
	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI	HR	95 % CI
Work characteristics												
Function level	0.56	0.39-0.78	0.58	0.32-1.04	0.56	0.41-0.77	0.76	0.52-1.10	1.23	0.82-1.83	1.15	0.64-2.08
Psychosocial job demands												
Psychological job demands	1.00	0.89-1.11	0.91	0.76-1.10	1.08	0.98-1.19	0.87	0.75-1.01	0.83	0.69-1.00	0.89	0.68-1.16
Decision authority	1.03	0.94-1.12	0.78	0.60-1.02	1.03	0.95-1.13	1.06	0.83-1.35	1.13	0.98-1.31	2.05	1.00-4.21
Skill discretion	0.97	0.83-1.13	0.89	0.68-1.17	0.93	0.81-1.08	1.24	0.98-1.57	0.94	0.74-1.19	1.44	0.91-2.30
Relation with supervisor	0.88	0.69-1.13	0.89	0.57-1.41	0.91	0.72-1.15	0.85	0.59-1.22	0.80	0.55-1.17	1.00	0.51-1.96
Relation with co-workers	0.99	0.75-1.31	1.03	0.59-1.80	0.95	0.72-1.24	0.72	0.49-1.07	0.86	0.56-1.32	1.05	0.49-2.24
Physical job demands												
Perceived physical workload	1.06	1.00-1.12	1.13	1.03-1.24	1.04	0.99-1.10	1.02	0.94-1.10	1.09	1.00-1.19	0.89	0.75-1.05
Physical exposure	1.03	1.01-1.06	1.04	0.99-1.09	1.01	0.98-1.03	1.02	0.98-1.06	1.00	0.96-1.04	1.05	0.98-1.12
Other												
Job satisfaction	1.03	0.91-1.17	1.03	0.83-1.28	1.07	0.95-1.20	0.85	0.72-1.00	0.85	0.71-1.02	0.72	0.55-0.95
Job security	1.07	0.90-1.28	0.98	0.72-1.34	0.95	0.81-1.12	0.88	0.69-1.11	1.01	0.78-1.32	0.89	0.55-1.41
Work organization and communication	0.92	0.81-1.05	0.99	0.79-1.24	1.10	0.96-1.26	1.00	0.84-1.20	0.99	0.80-1.22	0.77	0.56-1.08

lems by shift workers (30). Also symptoms of insomnia are more prevalent among rotating shift workers compared to day workers (31). Likewise, a higher percentage of shift workers compared to day workers reported sleep complaints and insomnia at baseline. Sleep complaints and insomnia were assessed with a single, self-formulated item, which are not as sensitive as composed constructs. Many well validated questionnaires assessing sleep problems and insomnia exist. However, several other studies examining poor sleep and sickness absence also used a single item measure (26, 27). Sleep complaints among day workers protecting against absence ≥6 weeks might also be a Type I error, whereas the non-significant findings among shift workers might indicate shift workers consider sleep disturbances a part of the job or found a way to cope with sleep disturbances, e.g., napping before or after work (32). For other single items, like Bronchitis, GID, HBP and CVD, sensitivity issues are less likely, because they are often doctor diagnosed.

The reason for the outcome "leaving the organization" is unknown and should therefore be interpreted with great care. For older workers, leaving the organization might be due to (early) retirement or ill health. For younger workers it might be a next step in their career, which can positively affect sustainable employment. As a result, risk factors for and the interpretation of outcome measures related to sustainable employment might differ between older and younger workers. However, the sensitivity analysis for age groups revealed few differences between older and younger workers. This finding might well be due to a healthy worker effect, which is supposed to be more pronounced in a shift work population (33). The critical age for reduced shift work tolerance has been indicated to be around 40-50 years, with sleep quality and duration decreasing with increasing age till approximately 45 years of age, but remaining stable afterwards (34, 35). Considering the average age of the shift work population in this study of 44.5 years, a selection effect might already have occurred. On the other hand, reduced shift work tolerance with increasing age does not necessarily have to lead to selection out of shift work. Shift work-related complaints must be severe enough to outweigh any loss in financial benefits. Especially, when the living standard (e.g., mortgage) is based upon the salary including financial benefits.

Major strengths of this study are its prospective design and the large sample size. It is important to note, that despite the prospective nature of the design, the time frame of a cohort study is critical. In a perfect study, self-selection into exposure conditions is minimized, the cohort is identified before any exposure, and the cohort can be followed through the transition and for short- and long-term effects of the exposure (36). In this study, no information was available on selection into (shift) work. Furthermore, little is known about any previous (shift) work exposure. At baseline, shift and day workers were, on average, employed by Tata Steel for 21.5 years and 23.7 years respectively. No information was available on previous work schedules or job functions. Given the relative long time participants/workers have been employed by Tata Steel, a survivor effect might already have taken place. Finally, the time frame of this study might have been too short to detect any long term effects, especially given the above mentioned optimal conditions of a cohort study. Despite these considerations, in practice it is difficult to adhere to the optimal conditions of a cohort study due to ethical, logistical and time-based constraints. Still, in the future, more research is needed on the selection into and out of (shift) work, preferably in longer follow-up studies, starting when workers enter (shift) work.

This study was restricted by the variables of the health interview and the company registers. The individual and work-related characteristics were based on non-validated self-report measures, but checked by a company physician and discussed with the employee. Sustainable employment is a complex and multifactorial topic. Despite the number of individual and work-related characteristics in this study, it was not possible to account for all risk factors (e.g. educational level, family and financial situation) (7, 15, 16). Unmeasured constructs could maybe explain the few differences found between shift and day workers, and between older and younger workers. It is important to note that dichotomous outcome measures do not reflect sustainable employment, which can be viewed as an on-going effort. A life-course epidemiological approach, allowing for the incorporation of differences in duration of sickness absence, recurrence and transitions to other outcome measures, might be an interesting approach. Due to the relatively short follow-up period, a life-course approach might not be the most appropriate technique in this study, but can be used for future long lasting longitudinal studies.

The comparison between included and excluded workers showed that excluded workers were more at risk to be temporarily placed in less strenuous work or to leave the organization. Due to the length of the study period (five years) and the time between two health checks (3-4 years), it is reasonable to assume that workers who left the organization had a lower probability to receive a health check during the study period. No reasonable explanation was found why excluded workers were more prone to be temporarily placed in less strenuous work. The study sample was homogeneous in terms of gender, occupational group and working conditions, eliminating these possible sources of confounding. On the other hand, this also means that these results are not necessarily generalizable to females, other occupational groups or different working conditions.

In conclusion, in this study most of the characteristics predicting work outcomes related to sustainable employment were similar for shift and day workers, although some differences were observed pertaining CVD, HBP and sleep. Interventions aimed to enhance sustainable employment should focus on both individual and work-related characteristics. This study provides no evidence that group specific interventions for shift and day workers should be taking into account. Selection effects might have biased the results of this study. More research is needed on selection in and out of (shift) work in preferably longer follow-up studies.

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Appendix 2.A Individual and work related scales and items

	Cronbach's alpha	Range
Individual characteristics		
Health status - Mental complaints	0.67	0-4
do you often have the feeling of facing too many obstacles?		
do you often have nervous complaints?		
do you often have concentration problems?		
do you often have trouble remembering things?		
Health status - Fatigue	0.71	0-2
are you often tired?		
are you often sleepy or drowsy?		
Health status - Musculoskeletal pain and stiffness	0.63	0-5
often pain or stiffness in the shoulders, arms or legs		
often pain or stiffness in the hip, legs or feet		
often pain or stiffness in the neck		
often pain or stiffness in the lower back		
often pain or stiffness in the higher or middle back		
Health status - Work-related complaints	0.80	0-3
complaints are possibly related to work		
complaints are produced or worsened by work		
complaints hinder work		
Health status - Sleep complaints	-	0-1
Health status - Insomnia	-	0-1
Health status - High blood pressure	-	0-1
Health status - Cardiovascular disease	-	0-1
Health status - Gastrointestinal complaints	-	0-1
Health status - Bronchitis	-	0-1
Socio-demographic characteristics		
Age	-	18-63
Lifestyle		
Smoking (yes)	-	0-1
Alcohol use (yes)	-	0-1
Work family interference		
Social problems imposed by (irregular) working times	-	0-1

Appendix 2.A (continued) Individual and work related scales and items

	Cronbach's alpha	Range
Work characteristics		
Physical job demands - Perceived physical workload	0.79	0-7
work is physically very demanding		
experiencing a lot of hindrance of prolonged standing		
experiencing a lot of hindrance of lifting or carrying		
experiencing a lot of hindrance of working in a similar posture		
experiencing a lot of hindrance of regularly bending		
experiencing a lot of hindrance of extended reaching		
experiencing a lot of hindrance of making similar movements		
Physical job demands - Physical exposure	0.90	0-13
hindrance of vibrations or shock during work		
hindrance of cold		
hindrance of heat		
hindrance of temperature changes		
hindrance of breeze		
hindrance of dry air		
hindrance of moist air		
hindrance of lack of fresh air		
hindrance of light and/or lighting		
hindrance of stench		
hindrance of dust		
hindrance of smoke		
hindrance of vapour, mist or gas		
Job satisfaction	0.67	0-3
work usually interesting		
work suits you		
usually enjoy work		

Appendix 2.A (continued) Individual and work related scales and items

	Cronbach's alpha	Range
Function level		low/high
Psychosocial job demands		
Psychological job demands	0.55	0-3
work is mentally exhaustive		
work often implies time pressure		
work mounts up too often		
Decision authority	0.61	0-3
easy to take a day off		
work can be easily interrupted		
free to determine work procedure		
Skill discretion	0.57	0-2
sufficient opportunities to increase experience and knowledge		
sufficient opportunities for education		
Relation with supervisor	-	0-1
direct supervisor sufficiently takes into account employee's opinion		
Relation with co-workers	-	0-1
mutual atmosphere is good		
Job security	0.62	0-2
company offers sufficient assurance		
perspectives at the current company are good		
Work organization and communication	0.60	0-3
work usually well organized		
sufficient consultation		
sufficient communication about objectives and results		

CHAPTER 3

Sleep and need for recovery in shift workers: do chronotype and age matter?

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Abstract

This study examined associations of chronotype and age with shift-specific assessments of main sleep duration, sleep quality and need for recovery in a cross-sectional study among N=261 industrial shift workers (96.6% male). Logistic regression analyses were used, adjusted for gender, lifestyle, health, nap behaviour, season of assessment and shift schedule. Shift workers with latest versus earliest chronotype reported a shorter sleep duration (OR 11.68, 95% CI 3.31-41.17) and more awakenings complaints (OR 4.84, 95% CI 4.45-11.92) during morning shift periods. No associations were found between chronotype, sleep and need for recovery during evening and night shift periods. For age, no associations were found with any of the shift-specific outcome measures. The results stress the importance of including the concept of chronotype in shift work research and scheduling beyond the concept of age. Longitudinal research using shift-specific assessments of sleep and need for recovery are needed to confirm these results.

Introduction

Shift work is a common working time arrangement where workers replace each other within the same work process to maintain continuity over the working day or week. About 17% of workers in the EU and 15% in the US is involved in shift work (1, 2). Shift work can be burdening to workers due to disturbances of biological and social circadian rhythms, i.e. interference with the day/night rhythm. The adverse effects of shift work are well documented and comprise, amongst others, an increased risk of developing cardiovascular disease, gastrointestinal disease and metabolic syndrome (3-6). The most reported problem by shift workers is disturbed sleep (7).

Sleep of at least three out of four shift workers is affected (8). A misalignment between the internal circadian rhythm and the work schedule is considered to be a major cause of sleep problems. In particular, sleep after night shifts and before morning shifts is affected, resulting in a shortened sleep length of up to four hours (7, 9-11). Sleep debt can accumulate over the work week or shift cycle and without sufficient time to recover, individuals remain vulnerable to sleep loss (12, 13). Accumulated sleep loss is often used to explain the relationship between shift work and impaired cognitive performance, safety implications and an increased risk of lifestyle-related illness (14, 15).

Next to the impact of the work schedule, inter-individual variability in sleep duration and quality amongst shift workers is related to differences in the individual phase of entrainment (chronotype) (16-18). More specifically, sleep problems vary by shift and by shift schedule (19), with chronotype modulating shift-specific sleep duration and quality (11). Sleep duration and quality are most affected during night shift periods in early chronotypes, while later chronotypes show identical, if not larger levels of sleep debt and poor sleep during morning shift periods (11). Differences in sleep length between extreme chronotypes may amount to 2 hours. With respect to other dimensions of sleep quality, e.g. difficulties upon awakening, relations have not yet been established.

Another concept, to be examined yet in relation to chronotype among shift workers, is need for recovery. Need for recovery refers to the immediate need to recuperate from a day's work (20). Without sufficient time to recover, a vicious circle might start where extra effort has to be exerted at the beginning of each working period to rebalance the suboptimal state and to prevent performance breakdown (20). In the longer term, accumulated need for recovery is viewed as a precursor of prolonged fatigue and ill health (21).

Albeit longitudinal data are missing, chronotype changes with age (22, 23). Concurrently, age is associated with sleep and need for recovery. Sleep duration and sleep quality decrease up to the age of 45 years and remain stable afterwards (24, 25), while difficulties upon awakening are more common among younger workers (26). Furthermore, need for recovery varies with age (27, 28). Examining associations and distinct contributions of chronotype and age upon sleep and need for recovery might help to further clarify the relationship between chronotype and age. The objectives of this study were to examine associations of chronotype and age with shift-specific assessments of main sleep duration, sleep quality and need for recovery. It is hypothesised that:

1. Compared with early chronotypes, later chronotypes report shorter main sleep duration, more disturbed sleep, more awakening complaints and higher need for recovery during a morning shift period.
2. Compared with early chronotypes, later chronotypes report longer main sleep duration, less disturbed sleep, less awakening complaints and lower need for recovery during a night shift period.
3. Compared with younger shift workers, older shift workers report shorter main sleep duration, more disturbed sleep, more awakening complaints and higher need for recovery, irrespective of the type of shift.

Methods

Study design and procedures

A cross-sectional study was conducted within the sampling frame of the 'Shift Your Work' study among N=650 blue-collar shift workers of four industrial companies in the Netherlands. Three companies were part of a large multinational in the process industry. In these three companies, shift workers rotated between different tasks such as process monitoring (control room), repairing and taking care of logistics. One company operated in the chemical sector, producing photosensitive materials. In this company, tasks comprised quality inspection, process monitoring and providing technical assistance. All shift workers were informed about the design and aim of the study by the Human Resource Departments. Web-based and paper versions of the questionnaire were used. The Medical Ethics Committee of the University Medical Center Groningen provided ethical clearance. Participation in the study was voluntary and answers were processed anonymously.

Measurements

Chronotype, sleep duration and nap behaviour were measured with a shift work-accommodated version of the Munich Chronotype Questionnaire (MCTQShift, (29)). The MCTQShift comprises questions about the actual timing of sleep and wake behaviour (bed and rise times plus sleep latency, inertia, and timing and duration of naps) separately for each shift and the respective free days. Chronotype is based on mid-sleep (i.e. mid-point of sleep) on free days (MSF) corrected for the amount of sleep debt accumulated during the work week (MSFsc, (16, 30)). Sleep data on free days were missing of N=247 shift workers, due to an error in the questionnaire, which made it impossible to calculate chronotype for these participants. Therefore, we used mid-sleep after an evening shift (MSWE) as a proxy for chronotype. In a previous study, MSWE was shown to correlate with chronotype (r= .77; in N=175 shift workers using no alarm clock on free days, irrespective of alarm on work days (31)). Main sleep duration (SD) was calculated by the difference in sleep onset (SO) and sleep end (SE) separately for each shift, and dichotomised (>5 hours=0, ≤5 hours=1). Participants sleeping less than 3 and more than 12.5 hours were excluded. Nap behaviour was assessed by a single item asking whether participants nap (yes, no).

Sleep quality during the past 3 months was measured with the seven-item version of the Karolinska Sleep Questionnaire (KSQ), separately for the morning, evening and night shift (26, 32). The items concerned: (i) difficulties falling asleep, (ii) disturbed/restless sleep, (iii) repeated awakenings, (iv) premature awakenings, (v) difficulties waking up, (vi) non-refreshing sleep and (vii) exhausted at awakening. The response options were '1: Never, 2: Almost never, 3: Sometimes (once or more per month), 4: Mostly (once or more per week) and 5: Always (almost every day)'. Two indices were constructed: the Disturbed Sleep Index (DSI) by averaging item scores i-iv and the Awakenings complaints Index (AwI) by averaging item scores v-vii. Both indexes were dichotomised upon the upper-quartile (33).

Need for recovery (NFR) was measured with a subscale of the Dutch Questionnaire on Perception and Judgement of Work (VBBA, (34, 35). The scale consists of 11 dichotomous items representing short-term effects of a day of work (35-37). Need for recovery was measured separately for the morning, evening and night shift. The responses were summed and transformed into scores ranging from 0 to 100, with higher scores indicating higher need for recovery. A cut-off point of 54 was used to classify cases with high need for recovery, as suggested by Broersen et al (36).

Age was assessed by questionnaire and divided into four categories (≤35, 36-45, 46-55, >55). Covariates comprised gender, BMI, smoking (yes/no), alcohol use, number of doctor diagnosed chronic diseases, general health, season of assessment and work schedule. Covariates were included due to their relation with chronotype and sleep (38, 39) and assessed by questionnaire. BMI was calculated from the weight and length of workers (weight(kg)/length(m)2). Alcohol use was dichotomised upon a maximum of 14 glasses per week for males and seven for females (40). The number of chronic diseases was derived from the Work Ability Index (0, ≥1) (41). Self-rated health was assessed with the first question of the Short-Form 12 ("In general, would you say your health is: Excellent, very good, good, fair, poor (42)), and dichotomised into good/very good/excellent and poor/fair. Season of assessment was derived from the date of completing the questionnaire. Each company provided information about the work schedules (Table 3.1).

Statistical analyses

All participants with complete data were included in the analyses. We conducted independent samples t-test and Mann Whitney U test in case of non-parametric data to examine differences between participants with complete and incomplete data. Associations of chronotype and age with shift-specific sleep duration, sleep quality and need for recovery were examined in logistic regression, using early chronotype and the youngest age category (≤35 years) as reference category. Hypotheses 1-3 were tested crude (model 1), chronotype adjusted for age and age adjusted for chronotype (model 2) and model 2 additionally adjusted

Table 3.1 Shift schedule characteristcs
(M=Morning shift, E=Evening shift, N=Night shift, D=Day shift, x=day off)

Schedule	Work times				Sequence
	Morning shift	Evening shift	Night shift	Day shift	
1 3-shift	7:00-15:00	15:00-23:00	23:00-7:00		NNNNNxxEEEEExxMMMMMxx
2 5-shift 1	7:00-15:00	15:00-23:00	23:00-7:00		MMEENNxxxx
3 5-shift 2	7:00-14:00	14:00-23:00	23:00-7:00		MMEENNxxxx
4 5-shift 3	7:00-14:00	14:00-23:00	23:00-7:00		MMEExNNxxx
5 5-shift 4	7:00-14:00	14:00-23:00	23:00-7:00		MMMEENNxxxxxMMEEENNxxxxxMMEENNNxxxx
6 5-shift 5	6:30-14:00	14:00-22:00	22:00-6:30		MMMEENNxxxxxMMEEENNxxxxxMMEENNNxxxx
7 5-shift 6	7:00-14:00	14:00-23:00	23:00-7:00		MMMEExNNxxxxMMEEExNNxxxxMMEExNNNxxx
8 6-shift	6:00-14:00	14:00-22:00	22:00-6:00	8:00-16:00	MMEENxxxxMMENNxxxxMEENNxxxMMEENNxxx DDDDDxx

for gender, BMI, smoking, alcohol use, number of chronic diseases, self-rated health, nap behaviour, season of assessment and shift schedule (model 3). Sensitivity analyses were conducted for all three hypotheses by stratifying for nap behaviour (yes/no), for males only and for complete cases per shift. All analyses were performed using SPSS 20 (43).

Results

Study sample characteristics

A total of N=430 (66.2%) shift workers returned the questionnaire. Of these, N=147 (34.2%) had missing items for sleep parameters on work days, need for recovery, disturbed sleep, awakenings complaints and socio-demographic factors. Furthermore, N=22 (5.1%) shift workers were excluded due to sleep duration less than 3 hours (N=21) or more than 12.5 hours (N=1), resulting in a final study sample of N=261 shift workers with complete data. When comparing shift workers with complete versus incomplete data, shift workers with complete data reported less disturbed sleep (mean 2.28 vs 2.65, $p<0.01$), less awakenings complaints (mean 2.44 vs 2.71, $p=0.02$) and longer sleep duration (mean 5.78 hours vs 5.12 hours, $p>0.01$) during night shift periods. No other differences were observed.

Shift workers reported the highest need for recovery and the shortest sleep duration during night shift periods, whereas sleep was most disturbed, accompanied by most awakening complaints during morning shift periods (Table 3.2). Shift workers reported least disturbed sleep and awakenings complaints, lowest need for recovery, and the longest sleep duration during evening shift periods. The majority of the shift workers did not nap between two shifts (M:28.71%, E:4.46%, N:36.49%). For those who napped, most did so before or after a night shift.

Table 3.2 Characteristics of the study sample (N=261)

Age (Mean. SD)		44.36	8.43
Gender (N, %)	*Male*	252	96.55
	Female	9	3.45
BMI (Mean. SD)		26.42	3.68
Smoking (N. %)	*No*	191	73.18
	Yes	70	26.82
Alcohol use (N. %)	*≤14 alcoholic beverages/week*	230	88.12
	> 14 Alcoholic beverages/week	31	11.88
Chronic diseases	*No chronic disease*	82	31.42
	≥ 1 chronic diseases	179	68.58
General health	*Good-excellent*	226	86.59
	Poor-fair	35	13.41
MSWE (Mean. SD)		5.08	1.00
Season of assessment (N. %)	*Standard Time Zone*	22	8.43
	Daylight Savings Time	239	91.57
Nap behaviour (Yes) (N. %)	*Morning*	77	29.50
	Evening	11	4.21
	Night	90	34.48
Schedule (N. %)	*1 3-shift*	12	4.6
	2 5-shift 1	158	60.5
	3 5-shift 2	23	8.8
	4 5-shift 3	18	6.9
	5 5-shift 4	14	5.4
	6 5-shift 5	9	3.4
	7 5-shift 6	18	6.9
	8 6-shift	9	3.4
Sleep duration (Mean. SD)	*Morning*	5.85	1.02
	Evening	7.07	1.25
	Night	5.78	1.52
Disturbed sleep (Mean. SD)	*Morning*	2.28	0.98
	Evening	1.79	0.76
	Night	2.28	0.96
Awakenings complaints (Mean. SD)	*Morning*	2.49	1.07
	Evening	1.87	0.83
	Night	2.44	0.94
Need for recovery (Mean. SD)	*Morning*	29.65	28.09
	Evening	16.78	22.42
	Night	41.03	30.58

Hypotheses testing

Because the linearity assumption for MSWE with any of the outcome measures (sleep duration, disturbed sleep, awakenings complaints and need for recovery) was not met, chronotype was divided into quartiles.

Hypothesis 1: Compared with early chronotypes, later chronotypes report shorter sleep duration, more disturbed sleep, more awakenings complaints and higher need for recovery during a morning shift period.

Crude analyses showed that shift workers with latest versus earliest chronotype (Q4 vs. Q1) reported a shorter main sleep duration (OR 9.48, 95% CI 3.09-29.12), more awakenings complaints (OR 4.84, 95% CI 1.92-12.19) and a higher need for recovery (OR 2.36, 95% CI 1.04-5.37) during morning shift periods. When adjusted for age, the associations did not change substantially. After additional adjustment for selected covariates, the association between chronotype and main sleep duration became stronger (OR 11.68, 95% CI 3.31-41.17), remained similar for awakenings complaints (OR 4.84, 95% CI 4.45-11.92) and was no longer significant for need for recovery (OR 2.19, 95% CI 0.82-5.82).

Hypothesis 2: Compared with early chronotypes, later chronotypes report longer sleep duration, less disturbed sleep, less awakenings complaints and lower need for recovery during a night shift period.

Crude (OR 0.34, 95% CI 0.16-0.71) and age adjusted (OR 0.36, 95% CI 0.17-0.75) analyses showed that shift workers with latest versus earliest chronotype (Q4 vs. Q1) reported a longer main sleep duration during night shift periods. When additionally adjusted for selected covariates, the association between chronotype and sleep duration attenuated and became non-significant. No associations were found between chronotype and disturbed sleep, awakenings complaints and need for recovery during night shift periods.

Hypothesis 3: Compared with younger shift workers, older shift workers report shorter sleep duration, more disturbed sleep, more awakening complaints and higher need for recovery, irrespective of the type of shift.

Older workers (>55 years) reported shorter main sleep duration (OR 3.71, 95% CI 1.14-12.10) compared with younger workers (≤35). When adjusted for chronotype, and additionally for the selected covariates, the association attenuated and was no longer significant. No significant associations were found for age with disturbed sleep, awakenings complaints and need for recovery.

Sensitivity analyses

In the stratified analyses for nap behaviour, chronotype was during night shift periods for non-nappers associated with main sleep duration in Models 1 and 2, but not in Model 3. Non-nappers aged 46 and older reported more disturbed sleep during morning shift peri-

Table 3.3 Associations between mid-sleep after an evening shift (MSWE) with shift-specific Sleep duration (SD), Disturbed Sleep (DSI), Awakenings complaints (AwI) and Need For Recovery (NFR) (N=261, OR=Odds Ratio, 95% CI=95% Confidence Interval)

	Morning shift						Evening shift						Night shift					
	Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sleep duration																		
MSWE Q1																		
MSWE Q2	2.27	0.65-7.97	2.28	0.65-8.02	2.20	0.58-8.3	5.64	0.64-49.74	5.61	0.64-49.55	18.38	1.19-284.23	0.60	0.29-1.23	0.59	0.29-1.22	0.85	0.37-1.96
MSWE Q3	3.42	1.05-11.13	3.48	1.07-11.33	3.81	1.07-13.53	3.82	0.41-35.09	3.76	0.41-34.73	4.89	0.36-66.4	0.66	0.33-1.32	0.64	0.32-1.28	0.77	0.34-1.74
MSWE Q4	9.48	3.09-29.12	9.26	3-28.56	11.68	3.31-41.17	1.85	0.16-20.92	1.89	0.17-21.55	0.90	0.06-14.51	0.34	0.16-0.71	0.36	0.17-0.75	0.51	0.21-1.22
Disturbed sleep																		
MSWE Q1																		
MSWE Q2	1.35	0.51-3.53	1.33	0.5-3.49	1.07	0.39-2.93	0.77	0.31-1.92	0.76	0.3-1.89	0.67	0.24-1.91	0.88	0.37-2.08	0.87	0.36-2.07	0.96	0.36-2.55
MSWE Q3	1.67	0.67-4.13	1.58	0.63-3.93	1.37	0.51-3.66	0.73	0.3-1.77	0.70	0.28-1.7	0.72	0.26-2.02	0.97	0.43-2.22	0.94	0.41-2.16	0.94	0.36-2.44
MSWE Q4	2.28	0.94-5.5	2.53	1.04-6.2	1.86	0.7-4.95	0.89	0.38-2.11	0.96	0.4-2.27	0.95	0.35-2.63	0.40	0.15-1.05	0.41	0.15-1.11	0.53	0.17-1.65
Awakenings complaints																		
MSWE Q1																		
MSWE Q2	2.43	0.91-6.54	2.46	0.91-6.61	2.28	0.78-6.67	1.17	0.5-2.75	1.19	0.5-2.8	1.09	0.42-2.86	0.96	0.4-2.32	0.98	0.4-2.37	1.14	0.41-3.16
MSWE Q3	2.22	0.84-5.87	2.28	0.86-6.04	2.17	0.75-6.26	0.43	0.16-1.17	0.45	0.17-1.22	0.41	0.14-1.24	1.36	0.6-3.06	1.43	0.63-3.26	1.57	0.6-4.08
MSWE Q4	4.84	1.92-12.19	4.67	1.84-11.81	4.16	1.45-11.92	1.36	0.6-3.06	1.27	0.56-2.9	1.29	0.49-3.41	0.81	0.34-1.94	0.74	0.3-1.79	0.72	0.25-2.1
Need For Recovery																		
MSWE Q1																		
MSWE Q2	1.18	0.48-2.93	1.17	0.47-2.91	0.92	0.32-2.58	1.78	0.55-5.8	1.77	0.54-5.76	2.37	0.55-10.21	0.89	0.44-1.82	0.90	0.44-1.84	0.84	0.38-1.84
MSWE Q3	1.31	0.55-3.12	1.27	0.53-3.04	1.23	0.45-3.34	1.74	0.55-5.5	1.70	0.53-5.38	3.09	0.73-13.12	0.80	0.4-1.61	0.82	0.41-1.65	0.72	0.33-1.56
MSWE Q4	2.36	1.04-5.37	2.50	1.09-5.72	2.19	0.82-5.82	0.71	0.18-2.79	0.74	0.19-2.92	0.68	0.12-3.8	0.67	0.33-1.34	0.64	0.31-1.3	0.54	0.24-1.24

* Model 1=Univariate analysis, ** Model 2=Model 1 adjusted for age, *** Model 3=Model 2 additionally adjusted for gender, smoking, alcohol use, BMI, chronic diseases, general health, naps, season of assessment and shift schedule

Table 3.4 Associations between age with shift-specific Sleep duration (SD). Disturbed Sleep (DSI). Awakenings complaints (AwI) and Need For Recovery (NFR) (N=261. OR=Odds Ratio. 95% CI=95% Confidence Interval)

	Morning shift						Evening shift						Night shift					
	Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sleep duration																		
Age ≤35																		
Age 35-45	1.27	0.52-3.14	1.89	0.69-5.18	1.54	0.48-5.01	2.09	0.24-18.23	2.63	0.31-22.19	1.12	0.08-15.09	1.22	0.54-2.76	1.14	0.49-2.65	1.52	0.54-4.29
Age 45-55	0.55	0.21-1.45	0.86	0.3-2.48	0.65	0.18-2.31	0.88	0.09-8.95	0.99	0.1-9.87	0.24	0.01-6.02	1.74	0.78-3.89	1.57	0.68-3.58	1.91	0.65-5.57
Age >55	1.04	0.27-4.03	1.85	0.43-7.97	1.21	0.21-7.09	1.62	0.09-29.34	1.97	0.12-33.58	1.38	0.03-65.13	3.71	1.14-12.1	3.28	0.98-10.95	2.61	0.62-10.94
Disturbed sleep																		
Age ≤35																		
Age 35-45	2.19	0.7-6.88	2.63	0.81-8.58	1.98	0.52-7.52	2.06	0.65-6.5	2.05	0.65-6.49	1.94	0.5-7.5	1.40	0.48-4.1	1.35	0.46-3.98	2.19	0.49-9.73
Age 45-55	2.55	0.82-7.89	3.24	1-10.56	2.74	0.7-10.71	1.80	0.57-5.69	1.79	0.56-5.7	1.82	0.45-7.45	1.49	0.52-4.3	1.39	0.48-4.04	2.07	0.45-9.47
Age >55	2.36	0.52-10.78	3.12	0.65-14.99	1.79	0.3-10.76	2.36	0.52-10.78	2.34	0.51-10.79	2.44	0.4-14.87	2.46	0.61-9.95	2.26	0.55-9.21	1.70	0.27-10.53
Awakenings complaints																		
Age ≤35																		
Age 35-45	0.66	0.29-1.5	0.78	0.32-1.87	0.40	0.14-1.17	0.81	0.34-1.91	0.82	0.34-1.94	0.57	0.19-1.66	0.81	0.34-1.91	0.79	0.33-1.87	0.63	0.2-1.95
Age 45-55	0.51	0.22-1.19	0.65	0.27-1.59	0.32	0.1-0.97	0.45	0.18-1.1	0.45	0.18-1.13	0.25	0.08-0.83	0.55	0.23-1.34	0.53	0.22-1.3	0.33	0.1-1.11
Age >55	0.80	0.23-2.77	1.10	0.3-4	0.58	0.12-2.82	0.77	0.2-2.91	0.79	0.21-3.01	0.74	0.14-3.76	0.77	0.2-2.91	0.73	0.19-2.79	0.44	0.08-2.51
Need For Recovery																		
Age ≤35																		
Age 35-45	1.02	0.41-2.55	1.17	0.46-3.02	0.92	0.29-2.87	1.12	0.29-4.39	1.13	0.29-4.44	0.87	0.17-4.53	1.25	0.58-2.69	1.22	0.56-2.63	0.97	0.38-2.47
Age 45-55	1.06	0.43-2.62	1.29	0.5-3.31	0.81	0.25-2.66	1.31	0.35-4.99	1.33	0.34-5.11	1.05	0.2-5.67	0.75	0.35-1.63	0.73	0.33-1.58	0.41	0.15-1.1
Age >55	2.31	0.67-7.88	2.95	0.83-10.51	1.01	0.2-5.06	2.27	0.41-12.55	2.30	0.41-12.91	1.59	0.2-12.55	0.93	0.29-2.96	0.89	0.28-2.84	0.37	0.09-1.51

* Model 1=Univariate analysis. ** Model 2=Model 1 adjusted for age. *** Model 3=Model 2 additionally adjusted for gender. smoking. alcohol use. BMI. chronic diseases. general health. naps. season of assessment and shift schedule

ods compared to the reference group (≤35 years). No associations were found for nappers in all three models for any of the shifts (Appendices A and B). The sensitivity analyses for males only and for complete cases per shift (sample size morning shift N=310, evening shift N=313, night shift N=295) did not change the results.

Discussion

The objective of this study was to examine associations of chronotype and age with shift-specific assessment of main sleep duration, sleep quality and need for recovery. The hypotheses regarding associations between chronotype with shift-specific outcome measures were confirmed for the morning shift only (hypothesis 1), although the direction of the associations was as expected for night shift periods (hypothesis 2). In the fully adjusted model, later chronotypes reported shorter main sleep duration and more awakenings complaints during morning shift periods. The hypothesis regarding associations between age and shift-specific sleep and need for recovery (hypothesis 3) was not confirmed. Older shift workers did not report more sleep problems or higher need for recovery for any shift.

Hypothesis 1 was largely confirmed. In the fully adjusted model, later chronotypes reported shorter main sleep duration and more awakenings complaints during morning shift periods. Earlier, it was shown that the wake maintenance zone of later compared with earlier chronotypes is later in the evening, thereby impeding sleep initiation early in the evening (44). In addition, main sleep duration during morning shift periods is truncated by early wake up times. Shift workers do not proportionally change the time they go to bed before morning shifts according to timing of morning shifts (45), resulting in large variability in sleep onset, but a narrow distribution of sleep offset (11). In our study, the confidence interval for main sleep duration during morning shift periods is quite large. Few shift workers reported a main sleep duration shorter than five hours. By dichotomising into long (>5 hours) and short (≤5 hours) main sleep duration, power decreased. In contrast, main sleep duration during night shift periods is dependent on the ability to sleep during daytime, which might account for larger individual differences in sleep duration. More shift workers will sleep shorter than five hours during night shift periods, which is reflected by the smaller confidence intervals during night shift periods. Considering awakenings complaints, earlier research has shown that frequent awakenings complaints are common in early morning work (46, 47) as it is closer to the nadir, i.e. the circadian low early in the morning (48). For later chronotypes, the nadir is even later in the morning compared with early chronotypes, increasing difficulties awaking before morning shifts.

Hypothesis 2 was not confirmed. No associations were found for chronotype with main sleep duration, sleep quality and need for recovery during night shift periods, though, the direction of the associations was as expected. Later chronotypes have more flexibility in sleeping habits (49) and report less disturbed daytime sleep (11, 50). Later chronotypes sleep later within a 24h period, allowing them to sleep into the day (11). Several possible explanations can be pointed out for the non-significant results between chronotype with sleep and need for recovery during night shift periods in our study. First, nap behaviour might have influenced the results. The sensitivity analyses showed that by stratifying for nap behaviour, only for non-nappers an association was found between chronotype and sleep duration during night shift periods. Second, MSWE has shown to correlate well with chronotype, but is probably less sensitive than MSFE corrected for accumulated sleep debt over the work week (i.e. chronotype). Third, for our analyses only participants with complete data were included. Compared to participants with incomplete data, they reported longer sleep duration, less disturbed sleep and less awakenings complaints. This may have resulted in an underestimation of the associations between chronotype and the shift-specific outcome measures. Moreover, relatively more early chronotypes leave shift work (17), which might lead to a relatively later chronotyped shift work population. Such a selection out of the job might lead to a more pronounced association during morning shift periods. Earlier research has shown that levels of sleep debt and poor sleep are slightly higher for later chronotypes during morning shift periods than for earlier chronotypes during night shift periods (11), which is in line with our study.

Hypothesis 3 was not confirmed. In the fully adjusted model, no associations were found between age and any of the outcome measures, although the direction of the associations was in line with previous research. Older workers reported a shorter main sleep duration and more disturbed sleep, in particular for night shift periods, whereas younger workers reported more awakenings complaints. Still, compelling evidence for age-related differences in sleep among shift workers is lacking. In the 2011 review by Saksvik et al. (51), the authors conclude that inter-individual variation is larger than inter-age group variation. In another 2011 review by Blok and de Looze (24), the authors deducted that older shift workers have more sleep-related problems during night shift periods and younger workers during morning shift periods. Both reviews acknowledge the possibility of a "healthy shift worker effect". The healthy shift worker effect refers to leaving only those in shift work that tolerate shift work the best. Non-significant findings might also be due to the age distribution of our study sample. The vast majority of shift workers were between 36- and 55-years old. As a result, the oldest age group (>55 years), which is expected to be most affected, might be underpowered.

Until recently, early retirement regulations were still available in most shift work companies. In view of labour market shortages, most companies have abandoned these regulations. At this moment, a large group of shift workers, as illustrated by the age distribution of our study sample, is at the verge of working past the early retirement age till 65 years or even longer. Shift work companies are looking for ways to accommodate ageing shift workers to ensure sustainable employment, but so far evidence about age-related shift work tolerance is inconclusive (24, 25). Also our study found no age-related effects. Instead, chronotype might provide an opportunity to accommodate shift workers independent of age. In search for new work schedules (e.g., self-rostering), it might therefore be worthwhile to incorporate the "chronotype" of a shift worker next to age. Ingre et al. (52) have shown that self-rostering is related to personal fit, reflected by later chronotypes working relatively more hours during the evening and night compared with earlier chronotypes. While self-rostering seems a promising method to accommodate individual differences, such as chronotype, in terms of satisfaction with shift schedules (53), it is still unknown whether this kind of shift systems will indeed diminish adverse long-term outcomes (and thereby enhancing sustainable (shift) work participation).

Strength of this study is the use of shift-specific assessment of sleep and need for recovery in relation to chronotype. Previous studies mainly focused on the relation between chronotype and overall sleep and fatigue-related measures (25), while these relations differ per shift. As previously argued by Juda et al (2013a), shift work research might benefit from taking into account chronotype when investigating shift-specific outcomes. A limitation is the cross-sectional design of this study, so no causal inferences can be made. Longitudinal studies are needed to examine the temporal relation between chronotype, sleep quality and need for recovery. To date the relationship between chronotype and sleep and fatigue-related measures has predominantly been examined in cross-sectional studies (17). Also, a longitudinal study with repeated measurements at different ages might provide knowledge on the stability of chronotype over the working life-course. Similar remarks can be made regarding shift-specific main sleep duration, sleep quality and need for recovery. In contrast to Flo et al. (19) and Juda et al. (29), the outcome measures used in this study were not originally developed per shift. However, the results showed shift-specific differences in sleep quality and in need for recovery. Another limitation is the amount of missing items, which is probably due to the length of the questionnaire. Conducting analyses with complete cases per shift, revealed only marginal differences showing the robustness of the results. However, the sample size limited the power of the sensitivity analyses for nap behaviour. Previous studies have shown a nap duration of one hour after a morning shift and more than one hour before a night shift, which can be modified by chronotype (54, 55). Hence, our results warrant further research into the associations between chronotype, nap behaviour and 24-hour sleep duration. Furthermore, not only biological factors might influence sleep and fatigue-related measures, but also sleep medication (56), organisational culture, work-related characteristics and social life (57). Unfortunately, we were not able to adjust for these additional factors. Considering the gender proportion and the relatively homogeneous study population of blue-collar workers in the industrial setting, results of this study are not generalisable to females and other occupational groups. Future studies may examine whether our results can be replicated in other, predominantly female, occupational groups.

In conclusion, in a study sample of predominantly male industrial shift workers, associations were found between chronotype and shift-specific main sleep duration, sleep quality and need for recovery. No associations were found between age and sleep and need for recovery. In particular, later chronotype was associated with shorter main sleep duration and more awakenings complaints during morning shift periods. Sleep was most affected during a night shift period, reflected by shorter main sleep duration, more disturbed sleep, more awakenings complaints, and a higher need for recovery. The results of this study indicate chronotype, rather than age, offers an interesting opportunity to individualize shift work schedules to reduce sleep-related problems. The application of such tailored shift work schedules should be further examined. Furthermore, longitudinal studies are needed to examine the long-term effects of chronotype on sleep and fatigue-related measures.

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Appendix 3.A1 Associations for nappers between mid-sleep after an evening shift (MSWE) with shift-specific Sleep duration (SD). Disturbed Sleep (DSI). Awakenings complaints (AwI) and Need For Recovery (NFR) (OR=Odds Ratio. 95% CI=95% Confidence Interval)

	Morning shift						Evening shift						Night shift					
	Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sleep duration																		
MSWE Q1																		
MSWE Q2	-		-		-		-		-		-		1.23	0.34-4.52	1.41	0.37-5.32	2.28	0.48-10.94
MSWE Q3	-		-		-		-		-		-		0.95	0.31-2.92	0.87	0.28-2.75	1.09	0.3-3.93
MSWE Q4	-		-		-		-		-		-		1.14	0.31-4.22	1.45	0.37-5.73	1.77	0.39-8.12
Disturbed sleep																		
MSWE Q1																		
MSWE Q2	7.73	0.79-75.32	7.26	0.73-72.24	3.22	0.21-48.28	-		-		-		1.91	0.53-6.84	1.87	0.52-6.79	3.06	0.57-16.39
MSWE Q3	7.44	0.82-67.37	8.64	0.92-81.15	4.33	0.29-64.25	-		-		-		1.76	0.55-5.62	1.79	0.56-5.72	1.50	0.33-6.74
MSWE Q4	11.33	1.25-102.93	9.79	1.06-90.7	4.06	0.3-55.49	-		-		-		1.25	0.32-4.82	1.21	0.3-4.82	1.15	0.19-6.95
Awakenings complaints																		
MSWE Q1																		
MSWE Q2	10.20	1.07-97.41	9.71	0.99-94.94	2.92	0.13-63.51	-		-		-		1.91	0.53-6.84	1.77	0.49-6.42	2.52	0.5-12.56
MSWE Q3	10.93	1.23-97.04	13.21	1.42-123.01	38.77	1.74-865.62	-		-		-		2.06	0.65-6.51	2.19	0.68-7	2.01	0.48-8.35
MSWE Q4	20.78	2.3-187.67	18.34	1.99-169.06	19.81	1.22-322.24	-		-		-		1.64	0.44-6.08	1.41	0.36-5.45	1.01	0.17-6.01
Need For Recovery																		
MSWE Q1																		
MSWE Q2	2.60	0.63-10.79	2.52	0.6-10.52	0.44	0.05-3.47	-		-		-		1.57	0.47-5.23	1.50	0.44-5.05	1.42	0.33-6.15
MSWE Q3	2.00	0.53-7.49	2.07	0.55-7.82	1.99	0.31-12.79	-		-		-		1.45	0.5-4.23	1.50	0.51-4.39	1.07	0.3-3.86
MSWE Q4	2.60	0.67-10.06	2.45	0.62-9.65	1.12	0.16-7.64	-		-		-		0.70	0.21-2.36	0.64	0.18-2.25	0.54	0.11-2.63

* Model 1=Univariate analysis. ** Model 2=Model 1 adjusted for age. *** Model 3=Model 2 additionally adjusted for gender. smoking. alcohol use. BMI. chronic diseases. general health. naps. season of assessment and shift schedule

Appendix 3.A2 Associations for nappers between age with shift-specific Sleep duration (SD). Disturbed Sleep (DSI). Awakenings complaints (AwI) and Need For Recovery (NFR) (OR=Odds Ratio. 95% CI=95% Confidence Interval)

	Morning shift						Evening shift						Night shift					
	Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sleep duration																		
Age ≤35																		
Age 35-45	2.25	0.22-23.32	1.81	0.13-25.85	-		-		-		-		3.33	0.81-13.67	3.34	0.81-13.83	4.97	0.72-34.11
Age 45-55	0.55	0.05-6.25	0.62	0.04-9.16	-		-		-		-		4.20	1.09-16.24	3.90	0.99-15.43	5.92	0.76-46.26
Age >55	1.09	0.09-13.78	2.07	0.12-34.39	-		-		-		-		3.73	0.65-21.58	3.68	0.63-21.39	4.26	0.46-39.72
Disturbed sleep																		
Age ≤35																		
Age 35-45	0.26	0.04-1.9	0.22	0.03-1.68	0.26	0.01-4.52	-		-		-		1.37	0.33-5.72	1.38	0.33-5.72	9.65	0.56-165.86
Age 45-55	0.25	0.04-1.75	0.26	0.04-1.89	0.28	0.02-5.06	-		-		-		0.76	0.19-3.03	0.76	0.19-3.12	3.95	0.23-69.16
Age >55	0.11	0.01-1.15	0.12	0.01-1.24	0.03	0-1.17	-		-		-		0.75	0.13-4.49	0.75	0.13-4.5	0.78	0.03-22.96
Awakenings complaints																		
Age ≤35																		
Age 35-45	0.44	0.06-3.16	0.35	0.04-2.72	-	0-0	-		-		-		0.96	0.24-3.83	0.96	0.24-3.83	2.22	0.26-18.78
Age 45-55	0.33	0.05-2.3	0.35	0.05-2.61	-	0-0	-		-		-		0.60	0.16-2.27	0.61	0.16-2.36	0.69	0.07-6.53
Age >55	0.18	0.02-1.64	0.19	0.02-1.86	-	0-0	-		-		-		0.53	0.09-3.03	0.53	0.09-3.05	0.16	0.01-4.27
Need For Recovery																		
Age ≤35																		
Age 35-45	0.44	0.06-3.16	0.42	0.06-3.01	0.06	0-1.64	-		-		-		0.54	0.13-2.22	0.53	0.13-2.21	0.79	0.1-6.07
Age 45-55	0.43	0.06-2.96	0.45	0.07-3.09	0.06	0-1.5	-		-		-		0.45	0.12-1.75	0.40	0.1-1.63	0.64	0.08-5.06
Age >55	0.67	0.08-5.3	0.70	0.09-5.59	0.06	0-2.1	-		-		-		0.88	0.16-4.87	0.84	0.15-4.75	1.03	0.1-11.1

* Model 1=Univariate analysis. ** Model 2=Model 1 adjusted for age. *** Model 3=Model 2 additionally adjusted for gender. smoking. alcohol use. BMI. chronic diseases. general health. naps. season of assessment and shift schedule

Appendix 3.B1 Associations for non-nappers between mid-sleep after an evening shift (MSWE) with shift-specific Sleep duration (SD). Disturbed Sleep (DSI). Awakenings complaints (AwI) and Need For Recovery (NFR) (OR=Odds Ratio. 95% CI=95% Confidence Interval)

	Morning shift						Evening shift						Night shift					
	Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sleep duration																		
MSWE Q1																		
MSWE Q2	1.94	0.53-7.16	1.98	0.53-7.32	1.32	0.32-5.42	5.58	0.63-49.31	5.57	0.63-49.32	14.61	0.9-238.07	0.53	0.2-1.42	0.51	0.19-1.4	0.68	0.22-2.08
MSWE Q3	2.49	0.71-8.78	2.53	0.72-8.94	2.16	0.56-8.28	2.68	0.27-26.45	2.67	0.27-26.51	3.19	0.22-47.17	0.53	0.2-1.42	0.52	0.19-1.4	0.79	0.26-2.4
MSWE Q4	4.52	1.37-14.91	4.40	1.33-14.57	4.49	1.22-16.52	1.81	0.16-20.52	1.82	0.16-20.73	1.09	0.06-20.57	0.22	0.07-0.66	0.22	0.07-0.66	0.31	0.09-1.1
Disturbed sleep																		
MSWE Q1																		
MSWE Q2	0.73	0.23-2.31	0.64	0.2-2.07	0.55	0.16-1.97	0.83	0.33-2.12	0.81	0.32-2.07	0.72	0.25-2.1	0.54	0.16-1.88	0.45	0.12-1.62	0.45	0.11-1.91
MSWE Q3	0.97	0.33-2.87	0.90	0.3-2.71	0.77	0.23-2.58	0.76	0.31-1.87	0.72	0.29-1.8	0.76	0.27-2.15	0.54	0.16-1.88	0.48	0.13-1.71	0.37	0.08-1.64
MSWE Q4	1.34	0.48-3.7	1.57	0.55-4.49	1.23	0.38-3.98	0.87	0.36-2.12	0.92	0.37-2.25	0.97	0.34-2.79	0.16	0.03-0.82	0.16	0.03-0.83	0.13	0.02-0.94
Awakenings complaints																		
MSWE Q1																		
MSWE Q2	1.44	0.46-4.57	1.48	0.47-4.69	1.75	0.47-6.47	1.04	0.43-2.57	1.07	0.43-2.64	0.98	0.36-2.65	0.65	0.18-2.36	0.73	0.2-2.69	0.65	0.15-2.86
MSWE Q3	0.98	0.29-3.28	0.99	0.29-3.36	0.95	0.24-3.74	0.45	0.16-1.23	0.47	0.17-1.28	0.41	0.14-1.24	0.97	0.29-3.2	1.04	0.31-3.48	0.83	0.2-3.43
MSWE Q4	2.87	1-8.22	2.77	0.96-7.98	3.13	0.89-10.98	1.15	0.49-2.71	1.10	0.46-2.6	1.09	0.4-2.97	0.63	0.19-2.14	0.59	0.17-2.04	0.57	0.12-2.62
Need For Recovery																		
MSWE Q1																		
MSWE Q2	0.65	0.17-2.48	0.64	0.17-2.45	0.57	0.14-2.41	1.93	0.53-6.97	1.87	0.51-6.79	2.20	0.47-10.32	0.75	0.3-1.9	0.80	0.31-2.05	0.67	0.24-1.92
MSWE Q3	0.79	0.22-2.81	0.78	0.22-2.78	0.81	0.21-3.15	2.10	0.61-7.2	1.99	0.57-6.87	3.28	0.73-14.8	0.53	0.2-1.4	0.55	0.21-1.45	0.42	0.14-1.28
MSWE Q4	2.35	0.81-6.83	2.41	0.82-7.07	2.34	0.71-7.78	0.43	0.08-2.44	0.46	0.08-2.61	0.55	0.08-3.98	0.73	0.3-1.78	0.71	0.29-1.74	0.48	0.16-1.44

* Model 1=Univariate analysis. ** Model 2=Model 1 adjusted for age. *** Model 3=Model 2 additionally adjusted for gender. smoking. alcohol use. BMI. chronic diseases. general health. naps. season of assessment and shift schedule

Appendix 3.B2 Associations for non-nappers between age with shift-specific Sleep duration (SD), Disturbed Sleep (DSI), Awakenings complaints (AwI) and Need For Recovery (NFR) (OR=Odds Ratio, 95% CI=95% Confidence Interval)

	Morning shift						Evening shift						Night shift					
	Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***		Model 1*		Model 2**		Model 3***	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sleep duration																		
Age ≤35																		
Age 35-45	1.05	0.39-2.84	1.41	0.48-4.12	0.99	0.25-3.88	2.72	0.32-22.94	2.62	0.31-22.13	1.37	0.1-18.76	0.82	0.28-2.41	0.71	0.23-2.17	0.91	0.24-3.40
Age 45-55	0.57	0.19-1.65	0.75	0.24-2.35	0.53	0.13-2.25	0.72	0.06-8.21	0.68	0.06-7.73	0.26	0.01-8.1	0.93	0.32-2.75	0.86	0.28-2.62	1.24	0.31-4.95
Age >55	1.19	0.11-13.3	1.78	0.15-21.72	0.89	0.06-13.86	2.06	0.12-34.95	1.88	0.11-32.16	7.32	0.17-320.56	2.37	0.41-13.75	1.71	0.28-10.41	2.40	0.28-20.47
Disturbed sleep																		
Age ≤35																		
Age 35-45	7.11	0.89-56.63	10.10	1.17-87.02	13.95	0.76-256.55	2.08	0.66-6.56	2.06	0.65-6.52	2.10	0.54-8.22	2.55	0.3-21.78	2.37	0.27-20.73	2.46	0.17-34.65
Age 45-55	8.70	1.10-68.76	12.51	1.46-107.36	19.43	1.00-376.62	1.66	0.52-5.31	1.64	0.51-5.27	1.70	0.41-7.08	3.79	0.45-31.58	3.76	0.44-32.13	4.55	0.32-64.72
Age >55	31.00	1.90-506.77	51.12	2.76-946.75	159.35	4.13-6143.36	2.29	0.5-10.47	2.25	0.49-10.38	2.27	0.37-14.11	9.60	0.72-127.53	7.44	0.54-101.87	4.16	0.17-99.27
Awakenings complaints																		
Age ≤35																		
Age 35-45	0.59	0.22-1.54	0.76	0.27-2.12	0.46	0.13-1.65	0.78	0.32-1.92	0.78	0.32-1.94	0.58	0.2-1.74	0.79	0.25-2.51	0.76	0.24-2.45	0.44	0.10-1.99
Age 45-55	0.41	0.15-1.12	0.52	0.18-1.53	0.26	0.07-1.02	0.45	0.17-1.18	0.46	0.17-1.2	0.29	0.09-0.98	0.40	0.11-1.45	0.39	0.11-1.42	0.29	0.06-1.48
Age >55	2.56	0.31-21	3.93	0.43-35.62	3.28	0.29-36.6	0.86	0.22-3.28	0.87	0.22-3.35	0.75	0.14-3.94	0.67	0.06-6.87	0.62	0.06-6.51	0.57	0.04-8.59
Need For Recovery																		
Age ≤35																		
Age 35-45	-		-		-		1.53	0.31-7.56	1.52	0.31-7.59	1.09	0.18-6.53	-		-		-	
Age 45-55	-		-		-		1.70	0.35-8.27	1.70	0.34-8.34	1.27	0.2-7.99	-		-		-	
Age >55	-		-		-		3.40	0.51-22.5	3.39	0.5-22.76	1.94	0.21-17.97	-		-		-	

* Model 1=Univariate analysis. ** Model 2=Model 1 adjusted for age. *** Model 3=Model 2 additionally adjusted for gender. smoking. alcohol use. BMI. chronic diseases. general health. naps. season of assessment and shift schedule

CHAPTER 4

Need for recovery among male technical distal on-call workers

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Abstract

The objectives of this study were to 1) examine whether need for recovery differs between workers (i) not on-call, (ii) on-call but not called, and (iii) on-call and called, and 2) investigate associations between age, health, work and social characteristics with need for recovery for the three scenarios (i-iii). Cross sectional data of N=169 Dutch distal on-call workers were analysed with multivariate logistic regression. Need for recovery differed significantly between the three scenarios (i-iii), with lowest need for recovery for scenario (i) 'not on-call' and highest need for recovery for scenario (iii) 'on-call and called'. Poor mental health and high work-family interference were associated with higher need for recovery in all three scenarios (i-iii), whereas high work demands was only associated with being on-call (ii and iii). The results suggest that the mere possibility of being called affects need for recovery, especially in workers reporting poor mental health, high-work demands and work family interference.

Introduction

One in five EU working time arrangements include regular on-call periods, requiring an individual's availability outside usual working hours (1). On-call work is common in professions that have to provide 24/7 coverage, but that do not require the amount of evening, night and weekend work for full shift coverage. During on-call services, workers either stay at the workplace (proximal on-call, which is common in e.g. healthcare) or they stay outside the workplace, but in vicinity (e.g. home) ready to be called back in case their presence is needed (distal on-call, which is common in e.g. technical professions) (2).

To date, most studies focused on proximal on-call work, especially among medical interns and residents. In the medical setting, proximal on-call work often coincides with long working hours. The combination of proximal on-call work and long working hours raised concerns about employee health (3). Only a few studies have examined distal on-call work and health. A literature review till the year 2000 has shown that being on-call negatively impacts sleep, mental health and social life among distal on-call workers (4). More recent studies on distal on-call workers have also shown increased levels of stress, anxiety, irritation and negative mood when being on-call (2, 5, 6). Recently, Cebola and colleagues (7) proposed a research framework to better understand and manage the risk of distal on-call work, based on their studies in UK distal on-call railway maintenance workers. The framework links on-call work and arrangement with effects on performance, attitude and well-being. Personal factors, work characteristics and on-call intensity and frequency are incorporated as possible effect moderators. In the author's view, the inherent unpredictability of 'being called or not' is the key differentiating factor between distal on-call work and other types of working time arrangements. Other studies support this idea by showing that the mere possibility of being called affects sleep quality, irritation, mood, and social and domestic activities (6, 8-10).

In addition, distal on-call workers may experience problems with detachment from work (2), which is critical to unwind and reduce short-term work-induced fatigue, i.e. need for recovery. Need for recovery after work refers to the immediate need to recuperate from work-induced fatigue (11). Without an opportunity to recover, extra effort has to be exerted at the start of each working period to rebalance the suboptimal psychological state and, prevent performance breakdown (11). Chronic need for recovery might lead to prolonged fatigue and long-term ill health (12). Prospective associations have been found between high need for recovery and health complaints, as well as sickness absence (12-14). In addition, higher levels of need for recovery are associated with older age, lower educational level, increased work-family conflict, high work demands and more working hours (11, 15-20).

The vast majority of studies on need for recovery have been performed in workers with regular daytime jobs, but whether different working time arrangements pose a differential effect on someone's need for recovery remains largely unclear. Jansen et al (21) found increased need for recovery among shift workers compared to non-shift workers, which attenuated substantially when adjusted for work-related factors (decision latitude, psychological job demands, physical and emotional demands). The authors argued that either work schedules might not significantly contribute in explaining need for recovery levels, or that shift workers might perceive their work as more demanding and thereby adjusting for work-related factors might lead to an underestimation of the association between shift work and need for recovery. Recovery is an important aspect when designing work schedules. To date, no study has examined need for recovery among distal on-call workers.

Similar to sleep quality, irritation, mood, and social and domestic activities, also need for recovery might differ for 'being on-call or not'. Previous studies differentiating between 'being on-call or not', assessed the different on-call scenarios separately using momentary ratings, e.g. diaries (6, 22). Momentary assessments, i.e. assessing the current state of a person, will reduce recall bias (23). These techniques are demanding for participants, resulting in relatively small sample sizes (5, 6, 22). Alternatively, retrospective assessment of the different on-call scenarios allows to include larger samples of workers. Compared to momentary ratings, participants report consistently higher levels of somatic complaints like pain and fatigue in retrospective assessments (24, 25). Yet, the levels of agreement are moderate to high (25). Although not preferred, retrospective assessments are common in shift work research. A number of validated questionnaires exist that are extensively used to retrospectively assess e.g. health, sleep quality and sleep duration for different work shifts (26-28). Retrospective assessment might also provide to be useful for assessing need for recovery and sleep separately for different on-call scenarios.

Therefore, the current study tested the following hypotheses: 1) workers report higher levels of need for recovery, disturbed sleep and awakening complaints when on-call but not called compared to not on-call, and on-call and called compared to on-call but not called, and 2) high levels of need for recovery in these three on-call scenarios are associated with older age, poor health, more social and caring conflicts and high work demands.

Methods

Study sample and procedure

This cross-sectional study is part of the larger 'Shift Your Work' project examining the effects of different working time arrangements on health, work functioning and social life. In total, N=280 technical distal on-call workers of a company taking care of the infrastructure of the gas distribution system in the Netherlands received a paper questionnaire between October and November 2011. Outside on-call periods, all workers worked during daytime hours (7:45-16:45 h, including breaks). Once every four weeks workers were one week on-call, starting on a Friday at 16:45 h and ending on a following Friday at 16:45 h. During on-call periods, workers are required to be reachable within 60 minutes in case their presence is needed (e.g. to verify a call of a possible gas leak). If possible, problems are handled by phone. All distal on-call workers were informed about the design and aim of the study by the Human Resource department and their direct supervisors. This study adhered to the ethical standards of the Declaration of Helsinki and guidelines of the association of universities in the Netherlands (29). Ethical approval was provided by the Medical Ethics committee of the University Medical Center Groningen (METc 2010.332).

Measurements

Age

Age was calculated from the date of birth and divided into four age categories (≤35, 36-45, 46-55, ≥56) (18).

Health characteristics

General health was assessed with the Short Form 12, a 12-item generic health status measure covering mental (MCS12) and physical (PCS12) health-related quality of life (30). The items were scored and by algorithm transformed into a norm-based mean of 50 and standard deviation of 10 (30). Scores range from 0 to 100, with higher scores indicating a better general health. MCS12 and PCS12 scores were dichotomised based on norm scores in the Dutch population (31).

Sleep quality was assessed with the Karolinska Sleep Questionnaire (32, 33), separately for i) not being on-call, ii) being on-call but not called, and iii) being on-call and called. Sleep quality was measured with seven items, comprising two indices: Disturbed Sleep Index (difficulties falling asleep, disturbed/restless sleep, repeated awakenings, premature awakenings) and Awakening Complaints Index (difficulties waking up, non-refreshing sleep, exhausted at awakening). Response categories were: '1: Never, 2: Almost never, 3: Sometimes (once or more per month), 4: Mostly (once or more per week), and 5: Always (almost every day)'. Scores were summed and averaged (1-5), with higher scores reflecting lower sleep quality.

Fatigue was measured with the subscale 'fatigue severity' of the Checklist Individual Strength (34, 35). The scale fatigue severity comprises 8 statements about general fatigue in the past two weeks (i.e. "I feel fit"). The response to each statement was scored on a 7-point Likert-scale from "1=Yes, that is true" to "7=No, that is not true". Scores were summed, resulting in a score ranging from 8-56 with higher scores indicating higher fatigue levels.

Work characteristics

Work demands were assessed with eleven self-constructed items tailored to the work demands of the specific population of technical distal on-call workers: '1: irregular working times, 2: night work, 3: amount of work, 4: organization of work, 5: getting a grip on work, 6: coordination with others, 7: sound/noise, 8: lighting conditions, 9: wearing personal equipment, 10: working outside, and 11: working alone. The response options to each item varied on a 4-point Likert-scale from Light, Normal, Heavy to Very heavy. The items were summed and averaged, with higher scores indicating higher work demands. The Cronbach's alpha for work demands was 0.72.

Social characteristics

Work Family Interference was assessed with ten adapted items from the Survey Work-home Interaction Nijmegen (SWING) (36). The adaptations to the SWING aimed to focus specifically on how on-call arrangements affect work-home interactions (e.g. my work schedule allows me to fulfil domestic obligations). The ten items were scored on a 4-point Likert-scale ((almost) never, sometimes, often, (almost) always). The scores were summed and averaged, with higher scores indicating more work family interference. The Cronbach's alpha for work family interference was 0.84.

Care for children was measured by household composition. Answers were categorized into living with children at home (yes/no).

Need for recovery

Need for recovery was assessed with a subscale of the Dutch Questionnaire on Perception and Judgement of Work (VBBA) (37) reflecting the immediate need for recovery after a day's work, separately for three scenarios: i) not being on-call, ii) on-call but not called, and iii) on-call and called. Need for recovery was measured with eleven dichotomous (yes/no) statements (38, 39). The scores for each scenario were summed, converted into a range of 0-100 with higher scores indicating higher need for recovery. For the analyses, the scores were dichotomized upon the upper quartile, with the lowest three quartiles as reference category.

Sensitivity analyses

Due to ethical restrictions, we were not able to link our questionnaires with individual data about the number and timing of calls from the company registers. Instead, self-reported data was collected about the average number of nights and weekends workers received a call, when on-call.

Statistical analyses

To examine possible selection effects, participants with complete data were compared to participants with incomplete data by independent samples t-test and Mann Whitney U test. Further statistical analyses were conducted for participants with complete data on relevant parameters only. Mean scores and standard deviations were given for the three different on-call scenarios for the dichotomized health, social and work characteristics. For hypothesis 1, Wilcoxon signed rank tests for non-linear data were used to test differences within subjects for the three on-call scenarios (i-iii). For hypothesis 2, logistic regression analyses were used to examine between subjects associations for age, health, work, and social characteristics with need for recovery. First, univariate associations were investigated (Model 1), followed by a multivariate analysis including age, health, work and social characteristics (Model 2). Sensitivity analyses were conducted including the average number of nights and weekends having been called, when on-call. All analyses were performed with SPSS version 20.0 (40).

Results

Participants with complete vs. incomplete data

A total of N=205 (response rate 73.2%) male distal on-call workers returned the questionnaire. Due to missing data on relevant parameters, the final study sample comprised N=169 (60.4%) distal on-call workers. Compared to participants with missing data, participants with complete data had significantly less disturbed sleep for the scenarios not on-call (mean 1.96 vs. 2.26, p=0.034), and on-call and called (mean 2.27 vs. 2.66, p=0.044). No significant differences were found for the other variables. The characteristics of the final study sample for participants with complete date are presented in Table 4.1.

Levels of need for recovery for age, health, work and social characteristics

Need for recovery scores showed a non-linear trend across the different age groups. Distal on-call workers with poor mental and physical health, and more disturbed sleep, awakening complaints, fatigue, work demands and work family interference reported consistently a higher need for recovery compared to distal on-call workers with good mental and physical health, and less disturbed sleep, awakening complaints, fatigue, work demands and work family interference. Distal on-call workers with care for children reported a higher need for recovery for the scenario not on-call (Table 4.2).

Hypothesis 1: workers report higher levels of need for recovery, disturbed sleep and awakening complaints when on-call but not called compared to not on-call, and on-call and called compared to on-call but not called

Workers reported significantly higher need for recovery, more disturbed sleep and more awakening complaints when being on-call, compared to when not on-call and significantly higher need for recovery, more disturbed sleep and awakening complaints when they received a call, compared to not being called (all p<0.001; Wilcoxon signed-rank tests), thereby confirming hypothesis 1 (Figure 4.1).

Hypothesis 2: high levels of need for recovery in three different on-call scenarios are associated with older age, poor health, more social and caring conflicts and high work demands

Univariate analyses (Model 1) showed that poor mental and physical health, more disturbed sleep, awakening complaints, fatigue, high work demands and work family interference were associated with higher need for recovery, irrespective of the on-call scenario. Age and care for children were not associated with need for recovery.

In the multivariate analysis (Model 2), the odds ratios (OR) for poor mental health and high work family interference attenuated, but remained statistically significant for all three scenarios. The OR for awakening complaints decreased, but remained statistically significant for the scenario on-call but not called (OR 3.84, 95% CI 1.33-11.08). The ORs for work demands attenuated and remained significant for the scenarios on-call but not called (OR

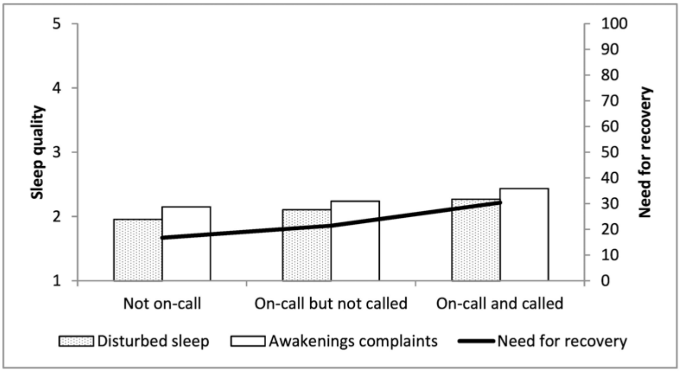

Figure 4.1. Need for recovery and sleep quality for three on-call scenario's

3.25, 95% CI 1.18-8.93) and on-call and called (OR 3.11, 95% CI 1.15-8.38) (Table 4.3). For both models, no difference was found between the odds ratios of the three scenarios due to overlapping confidence intervals.

For seven out of nine included factors, a crude association was found with need for recovery in Model 1, of which four remained in the multivariate analyses of Model 2, thereby largely confirming hypothesis 2.

Sensitivity analyses

Due to missing data on the number of received calls, N=161 participants were included for the sensitivity analyses. Except for the number of nights having been called for the scenario 'not on-call', participants with many received calls reported higher levels of need for recovery compared to those with few received calls (Table 4.4). In the full model including the average number of nights and weekends having been called, many awakening complaints and high work demands were found significant contributors for high need for recovery for the scenario "not on-call". No differences were observed for the other scenarios (data not presented).

Discussion

The current study examined associations between need for recovery and age, health, work and social characteristics among distal on-call workers for three different on-call scenarios i) not on-call, ii) on-call, but not called, iii) on-call and called. Overall, the findings confirmed our initial hypotheses. On-call workers reported different levels of need for recovery for the three scenarios, with the lowest need for recovery when 'not on-call' and the highest need for recovery when 'on-call and called'. Poor mental health, high work demands and high work family interference were associated with higher need for recovery. No associa-

Table 4.1. Description of study sample (N=169) (SD=Standard deviation)

	Mean	SD	Q3	N	%
Need for recovery					
Not on-call	16,72	21,87	27,27		
On-call but not called	21,41	25,04	36,36		
On-call and called	30,36	29,74	54,55		
Demographics					
Age	44,51	8,60			
Health characteristics					
Mental health	51,26	7,95			
Physical health	51,60	6,02			
Disturbed sleep					
Not on-call	1,96	0,78	2,25		
On-call but not called	2,11	0,85	2,75		
On-call and called	2,27	0,90	3,00		
Awakening complaints					
Not on-call	2,15	0,83	2,67		
On-call but not called	2,24	0,87	2,67		
On-call and called	2,43	0,90	3,00		
Fatigue severity	20,10	10,02	28,00		
Work characteristics					
Work demands	2,22	0,30	2,36		
Social characteristics					
Work family interference	1,86	0,50	2,20		
Household composition					
No care for children				53	32,12
Care for children				116	70,30

Table 4.2. Need for recovery scores for age, and health, work and social characteristics (N=169) (SD=Standard deviation)

		Not on-call		On-call but not called		On-call and called	
	N	Mean	SD	Mean	SD	Mean	SD
Demographics							
Age							
≤35	27	22.56	26.13	25.99	26.63	32.05	27.63
35-45	75	13.68	18.55	18.87	23.29	27.20	28.26
45-55	42	19.70	25.39	22.98	27.66	35.45	36.09
>55	25	14.55	18.92	21.45	24.32	29.45	24.38
Health status							
Mental health							
Good (>51)	107	9.97	15.13	13.04	18.98	20.26	24.90
Poor (≤51)	62	28.37	26.49	35.86	27.66	47.80	29.50
Physical health							
Good (>51)	110	12.98	18.57	15.39	19.56	23.54	26.42
Poor (≤51)	59	23.71	25.70	32.65	29.99	43.08	31.58
Disturbed sleep							
Low (Q1-Q3)	*	13.32	16.87	15.57	20.16	23.10	24.54
High (Q4)	*	29.29	31.87	41.55	29.68	51.64	33.51
Awakening complaints							
Low (Q1-Q3)	*	12.61	16.86	15.30	20.15	23.01	25.51
High (Q4)	*	32.47	30.49	40.50	29.15	47.85	31.96
Fatigue severity							
Low (Q1-Q3)	128	11.04	16.17	14.77	19.96	23.51	26.51
High (Q4)	41	34.48	27.42	42.17	28.01	51.75	29.39
Work characteristics							
Work demands							
Low (Q1-Q3)	128	13.30	18.71	16.72	21.64	23.90	26.03
High (Q4)	41	27.43	27.24	36.07	29.25	50.53	31.83
Social characteristics							
Household composition							
No care for children	53	13.21	21.29	19.07	25.29	26.07	26.75
Care for children	116	18.33	22.03	22.48	24.95	32.32	30.92
Work family interference							
Low (Q1-Q3)	131	11.86	17.16	15.31	20.20	23.58	26.29
High (Q4)	38	33.49	27.65	42.44	28.76	53.73	29.37

* DSI and AwI were assessed separately for three scenarios: For DSI (Low/High): not on call N=133/N=36, on-call but not called N=131/N=38, on-call and called N=126/N=43. For AwI (Low/High): not on-call N=134/35, on-call but not called N=128/N=41, on-call and called N=119/N=50)

Table 4.3. Associations between age, health, work, social characteristics and need for recovery for three on-call scenarios (N=169)[a], (OR=Odds ratio, 95% CI=95% Confidence Interval)

	Model 1[b]						Model 2[c]					
	Not on-call		On-call but not called		On-call and called		Not on-call		On-call but not called		On-call and called	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Demographics												
Age												
≤35	1.00		1.00		1.00		1.00		1.00		1.00	
35-45	0.66	0.23-1.85	0.66	0.23-1.85	0.64	0.24-1.74	0.67	0.15-3.03	0.60	0.14-2.58	0.42	0.11-1.60
45-55	0.89	0.29-2.73	1.43	0.49-4.18	1.46	0.52-4.11	0.50	0.09-2.61	1.01	0.21-4.74	0.73	0.17-3.09
>55	0.39	0.09-1.71	0.71	0.19-2.63	0.59	0.16-2.14	0.37	0.05-2.92	0.95	0.15-5.95	0.50	0.09-2.76
Health status												
Mental health												
Good (>51)	1.00		1.00		1.00		1.00		1.00		1.00	
Poor (≤51)	7.36	3.14-17.22	4.80	2.25-10.21	5.75	2.75-12.04	4.46	1.40-14.16	4.26	1.47-12.30	5.18	1.87-14.33
Physical health												
Good (>51)	1.00		1.00		1.00		1.00		1.00		1.00	
Poor (≤51)	3.52	1.62-7.65	3.50	1.68-7.29	3.77	1.85-7.70	1.51	0.42-5.44	1.82	0.58-5.79	2.66	0.92-7.68
Disturbed sleep												
Low (Q1-Q3)	1.00		1.00		1.00		1.00		1.00		1.00	
High (Q4)	4.29	1.88-9.75	7.28	3.26-16.26	6.32	2.95-13.54	2.71	0.79-9.33	1.56	0.51-4.81	2.23	0.78-6.36
Awakening complaints												
Low (Q1-Q3)	1.00		1.00		1.00		1.00		1.00		1.00	
High (Q4)	6.50	2.82-14.99	7.08	3.21-15.60	3.28	1.60-6.74	2.97	0.95-9.25	3.84	1.33-11.08	1.14	0.41-3.15
Fatigue severity												
Low (Q1-Q3)	1.00		1.00		1.00		1.00		1.00		1.00	
High (Q4)	6.51	2.88-14.72	3.77	1.75-8.14	4.55	2.14-9.69	2.03	0.57-7.21	0.75	0.22-2.51	0.93	0.29-2.94

Table 4.3 (continued)Associations between age, health, work, social characteristics and need for recovery for three on-call scenarios (N=169)[a]

	Model 1[b]						Model 2[c]					
	Not on-call		On-call but not called		On-call and called		Not on-call		On-call but not called		On-call and called	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Work characteristics												
Work demands												
Low (Q1-Q3)	1.00		1.00		1.00		1.00		1.00		1.00	
High (Q4)	3.91	1.76-8.72	5.14	2.37-11.18	5.29	2.47-11.32	2.82	0.93-8.52	3.25	1.18-8.93	3.11	1.15-8.38
Social characteristics												
Household composition												
No care for children	1.00		1.00		1.00		1.00		1.00		1.00	
Care for children	1.62	0.68-3.88	1.50	0.67-3.35	1.86	0.84-4.11	1.40	0.34-5.79	1.64	0.44-6.06	1.99	0.58-6.83
Work family interference												
Low (Q1-Q3)	1.00		1.00		1.00		1.00		1.00		1.00	
High (Q4)	7.73	3.36-17.78	7.28	3.26-16.26	6.46	2.94-14.16	5.75	1.95-16.95	4.92	1.74-13.93	4.12	1.46-11.63

[a] OR= Odds ratio, 95% CI = 95% Confidence interval, significant results are printed in bold, b model 1 includes univariate analyses, [c] Model 2 includes all independent variables

Table 4.4. Need for recovery scores for number of nights and weekends having been called (N=161) (SD=Standard deviation)

			Not on-call		On-call but not called		On-call and called	
When you were on-call…		N	Mean	SD	Mean	SD	Mean	SD
How many nights did you receive a call?	Q1-Q3	120	16.94	22.28	20.37	25,01	27.84	29.09
	Q4	41	15.81	19.33	24.66	24,70	39.45	30.62
How many weekends did you receive a call?	Q1-Q3	116	13.79	19.41	17.22	23,28	26.23	28.34
	Q4	45	24.04	24.91	32.40	25,92	42.57	30.62

tions were found between age and care for children with need for recovery.

Although not directly comparable due to differences in setting, population and measures, our finding of higher need for recovery being on-call (scenarios ii and iii) compared to not on-call (scenario i) shows similarities with previous findings regarding sleep quality and work family interference among distal on-call workers (2, 4-6). Not only performing extra work in addition to a regular daytime job, but also the inherent unpredictability of 'being called or not' might have contributed to higher need for recovery in our study population. In contrast to a study on sleep, stress and social activities among distal on-call Information Technology (IT) personnel (6), our study also showed higher need for recovery when being called compared to not being called during on-call duty. This finding may be due to the different measures in our study compared to the IT study or the relatively low number of calls in the IT study. In our study, no information was available on the objective number of calls, while it is possible that a threshold of number of calls has to be exceeded to affect need for recovery. Furthermore, the IT workers handled calls at home, while the technical workers of our study could be called to a worksite, which might have increased the burden experienced by the on-call workers.

The findings of our study are in line with studies showing associations between poor mental health, high work demands and high work family interference with higher need for recovery (12, 15, 18, 20). Poor mental health and more work family interference were associated with higher need for recovery, irrespective of the on-call scenario (i-iii), whereas high work demands was only associated with higher need for recovery when being on-call (scenarios ii and iii). A possible explanation for this finding might be that the negative impact of high work demands is attenuated by psychological detachment from work (41, 42). Detachment from work has been shown to be more difficult during on-call duty (2). However, because we did not assess work demands separately for the three scenarios (i-iii), future studies should explore possible associations for all scenarios.

Differences between the univariate and multivariate analyses might be due to the moderate to strong correlation of mental health with the other constructs (Appendix 4.A). For example, although being on-call impacts sleep quality and length negatively (6, 8-10) and sleep has been associated with need for recovery (11), no association was found between sleep quality and need for recovery in the full model. The association between sleep and need for recovery might be attenuated due to overlapping mechanisms with sleep and mental health (43). Furthermore, analyses for participants with complete and incomplete data revealed that participants with missing items had significantly more disturbed sleep for the scenarios not on-call, and on-call but not called compared to participants with complete data, which might have led to underestimation of the association between sleep and need for recovery.

In the present study, no association was found between age and need for recovery. Our finding is in line with a study among public sector workers in the Netherlands (44), though two other studies have found a significant increase in need for recovery up till an age of 55 years, with a decline in need for recovery with further increasing age (17, 18). Both studies do not reflect our specific worker population, because one study was conducted in the public sector in Belgium (17) and one among the general working population in the Netherlands excluding shift workers (18). Instead of age, different life phases might be related to need for recovery, in particular care for dependent children. After children get past the initial demanding years of intensive care, domestic responsibilities might be reduced. As a result, there might be an increased opportunity at home to recuperate from work induced fatigue. Our study found no association between presence of children and need for recovery. This is in line with a recent study showing that negative effects of distal on-call work (sleep deprivation, spousal sacrifice, intimacy and communication challenges, and diminished quality time with children) were consistent across different life phases (45).

Our study adds to the scarce literature on on-call workers, in particular distal on-call work, and is to our knowledge the first study to examine need for recovery among on-call workers. Previous studies on on-call workers only poorly described the studied working time arrangements, making it difficult to distinguish between important parameters of on-call work, e.g. distal and proximal on-call work. Strengths of our study are the clear description of the working time arrangement and because of the retrospective study design a relatively large sample size. Due to a reasonable response rate (73%), complete data were available for 60% of the initially addressed workers. The comparison between complete and incomplete datasets revealed only marginal differences between the two groups.

Our study has several limitations. First, our study was limited by the cross-sectional design. Hence, no causal inferences can be made. Second, in relation to the cross-sectional design, retrospective assessments are more susceptible for recall bias than momentary ratings (23). Although it has been suggested that higher levels of somatic complaints are reported in retrospective assessments compared to momentary ratings (24, 25), in our study levels of need for recovery are low during regular (non on-call) work periods compared to other studies (12, 13, 15, 17, 18, 44, 46). Whether this difference is due to our specific occupational group or the method of assessment, has to be further investigated. Third, no objective data were

available about the frequency and timing of actual calls. Therefore, we performed sensitivity analyses including the average number of nights and weekends having been called as a surrogate measure, which only showed marginal differences compared to our initial findings. Participants reporting higher need for recovery when called on weekends compared to called at night, might indicate a larger impact of weekend calls, e.g. calls interfering with social activities. Fourth, not all measures were assessed separately for the three scenarios, although measures of work demands and work-family interference might also differ between the three on-call scenarios. In the present study, distinction in assessments between the three on-call scenarios were kept to a minimum to align with other studies within the larger 'Shift Your Work' project.
Future studies are needed to more rigorously validate the methods we used, to help developing validated tools tailored to study distal on-call workers. For example, including both retrospective and, preferably real-time objective, momentary ratings to compare retrospective and momentary ratings. Furthermore, a prospective study design with repeated assessments of various constructs across different on-call scenarios would provide deeper insight into the impact of distal on-call work across time and to examine time course of cause and effect. In addition, the results of our study suggest that future studies may consider to also assess work demands and work-home interference for all three on-call scenarios. To date, little is known about the frequency and distribution of distal on-call shifts in relation to health and well-being. Due to novel technology replacing on-site presence of workers, opportunities for distal on-call work can be expected to increase in the future, emphasizing the need for longitudinal research to provide more insight in levels of need for recovery over time for distal on-call workers.

In summary, the present study examined need for recovery in an understudied worker population of distal on-call workers. The results of our study support our initial hypotheses; need for recovery differed between workers "not on-call", "on-call, but not called" and "on-call and called", and was in these three scenarios associated with health, work and social characteristics. The study findings suggest that the mere possibility of being called affects need for recovery, especially in workers with poor mental health, high work demands and high work family interference. To disentangle the effects of working time arrangements on need for recovery in more detail, future studies should describe working time arrangements of the study population more clearly, preferably using a longitudinal design with repeated measurements across different on-call scenarios.

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Appendix 4.A. Correlations dependend and independent variables

	Need for recovery (not on-call)	Need for recovery (on-call but not called)	Need for recovery (on-call and called)	Age	Mental Health	Physical health	Disturbed sleep (not on-call)	Disturbed sleep (on-call but not called)	Disturbed sleep (on-call and called)	Awakening complaints (not on-call)	Awakening complaints (on-call but not called)	Awakening complaints (on-call and called)	Fatigue severity	Work demands	Work family interference	Care for children
Need for recovery (not on-call)	1.00	0.82	0.70	-0.04	-0.49	-0.26	0.39	0.40	0.35	0.46	0.47	0.45	0.60	0.38	0.48	0.15
Need for recovery (on-call but not called)		1.00	0.84	-0.03	-0.51	-0.31	0.37	0.51	0.45	0.44	0.54	0.52	0.62	0.43	0.53	0.08
Need for recovery (on-call and called)			1.00	0.02	-0.52	-0.27	0.36	0.48	0.54	0.32	0.42	0.57	0.56	0.52	0.55	0.07
Age				1.00	0.00	-0.18	0.22	0.17	0.23	-0.03	-0.05	-0.03	0.09	0.17	-0.04	-0.04
Mental Health					1.00	0.14	-0.43	-0.46	-0.43	-0.42	-0.41	-0.44	-0.65	-0.27	-0.40	-0.09
Physical health						1.00	-0.28	-0.29	-0.28	-0.24	-0.25	-0.24	-0.56	-0.25	-0.24	-0.01
Disturbed sleep (not on-call)							1.00	0.86	0.75	0.51	0.48	0.42	0.36	0.26	0.18	-0.04
Disturbed sleep (on-call but not called)								1.00	0.88	0.48	0.60	0.54	0.40	0.38	0.31	-0.05
Disturbed sleep (on-call and called)									1.00	0.36	0.48	0.58	0.37	0.47	0.36	-0.05
Awakening complaints (not on-call)										1.00	0.93	0.78	0.44	0.16	0.24	-0.04
Awakening complaints (on-call but not called)											1.00	0.86	0.46	0.23	0.33	-0.04
Awakening complaints (on-call and called)												1.00	0.46	0.34	0.40	-0.03
Fatigue severity													1.00	0.36	0.42	0.06
Work demands														1.00	0.40	0.00
Work family interference															1.00	-0.04
Care for children																1.00

CHAPTER 5

Associations between shift schedule characteristics with sleep, need for recovery, health and performance measures for regular (semi-)continuous 3-shift systems

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Abstract

In this cross-sectional study associations were examined between eight shift schedule characteristics with shift-specific sleep complaints and need for recovery and generic health and performance measures. It was hypothesized that shift schedule characteristics meeting ergonomic recommendations are associated with better sleep, need for recovery, health and performance. Questionnaire data were collected from 491 shift workers of 18 companies with 9 regular (semi)-continuous shift schedules. The shift schedule characteristics were analysed separately and combined using multilevel linear regression models. The hypothesis was largely not confirmed. Relatively few associations were found, of which the majority was in the direction as expected. In particular early starts of morning shifts and many consecutive shifts seem to be avoided. The healthy worker effect, limited variation between included schedules and the cross-sectional design might explain the paucity of significant results.

Introduction

Shift work, i.e. workers succeeding each other at the same work station to perform the same job, is a widespread working time arrangement. Approximately 17% of the working population in the European Union (1) and 15% in the US (2) works in shifts. In the Netherlands, about 17% of the working population works in shifts (3). Shift work is applied to extend operating hours to evening, night or weekends, to provide coverage of necessary services, or to keep production processes running around the clock. While irregular shift systems are more common in the service sector (e.g. police and healthcare), the vast majority of industrial companies with shift work use a regular 2- or 3-shift system.

Shift work can be burdening to workers due to disturbances of biological and social circadian rhythms, and can negatively affect health and performance in the short and long term. Short-term effects of shift work comprise reduced sleep length and decreased sleep quality (4, 5). These effects differ per shift, with sleep most affected during early morning and night shift periods (6, 7). Without sufficient opportunity to recover, accumulated sleep loss is associated with generic outcomes like increased fatigue and impaired cognitive performance (8, 9). Long-term health effects of shift work refer to an increased risk of developing cardiovascular disease, metabolic disorders, breast cancer and gastrointestinal disorders (10-14).

The design of a shift system is regarded as a key determinant of shift work-related problems. A shift schedule that minimizes circadian disruption and accumulation of sleep loss across a shift cycle, and concurrently permits adequate recovery during days off, will be beneficial for sleep and alertness (15), as well occupational safety and long-term health. From this perspective, a set of ergonomic shift schedule criteria has been proposed to promote health, safety and social well-being (16). It is advised to 1) minimize the number of consecutive shifts, 2) minimize the number of consecutive working days, 3) provide adequate time to recover between two shifts, in particular after night shifts, 4) avoid early starts of the morning shift, 5) rotate forwards instead of backward (i.e. M(orning) to E(vening) to N(ight) shift instead of N-E-M), and 6) maximize the number of days off during the weekend (i.e. Saturday and Sunday).

Several reviews provide support for the ergonomic criteria by summarizing the effects of these criteria separately on sleep, recovery, health and performance (15, 17-19). It was shown that industrial performance efficiency is most impaired outside 7:00 to 19:00 and safety risk increases with consecutive shifts, in particular consecutive night shifts (criteria 1 & 2) (19). Quick returns between shifts (criterion 3) and early starts of the morning shifts (criterion 4) decrease sleep duration whilst increasing sleepiness (15, 18). A change towards a fast forward rotating schedule seems to be positively related to better sleep quality and alertness (criterion 5) (15, 17). Recovery is better during a weekend off than during two midweek-days taken off (criterion 6) (20).

Ergonomic shift scheduling recommendations are based on theoretical considerations and supported by mainly intervention studies, in which one or two shift schedule characteristics are changed. Shift schedule intervention studies are the preferred design when examining shift schedule characteristics. Intervention studies offer a powerful design and include both pre- and post-change measurements, and sometimes also a control group. However, intervention studies are hard to accomplish due to challenges implementing and evaluating shift system changes (21). A drawback of intervention studies is that self-reported effects of the intervention might be influenced by other factors than the schedule change, for example the workers' expectations and attitudes to the shift schedule change. Thus, a new shift schedule that minimizes circadian disruption and cumulative sleep loss may show more self-reported sleep and health problems because the workers' disapprove the intervention. The other way around is also possible, that by simply interfering and paying attention to workers' needs positive effects may be observed, i.e. the 'Hawthorne effect'. An alternative approach is to compare a large number of shift schedules that varies with respect to the scheduling recommendations and examine whether shift systems that fit with the ergonomic criteria's have less problems with self-reported sleep, recovery, health and performance. A drawback of such a cross-sectional design is the risk of confounding and that no causal inferences can be made.

Therefore, the aim of this study is to examine associations between ergonomic shift schedule criteria, separately and combined, for shift-specific and generic health and work functioning measures in a sample of 18 different company locations with 9 different shift schedules. It is hypothesized that shift schedule characteristics meeting the ergonomic criteria are associated with better sleep, recovery, health and performance.

Methods

Study sample and procedure

This cross-sectional study was conducted within the sampling frame of the 'Shift Your Work' study; a Dutch study about the effects of irregular night and shift work on health, work functioning and social life. A paper and web-based questionnaire was sent out to N=902 shift workers of nine different industrial companies with semi- (excluding weekends) and full-continuous (including weekends) production locations in the Netherlands. The inclusion period lasted from June 2011 to November 2013. All shift workers were informed about the design and aim of the study by the Human Resource departments. The Medical Ethics Committee of the University Medical Center Groningen provided ethical clearance.

Measurements

Ergonomic shift schedule criteria

The shift schedules were provided by the companies per department or location (Appendix 5.A). All but one shift schedule in our study were regular 3-shift systems, incorporating 3 shifts (morning, evening and night shifts) in a cyclic fashion operated by three or five teams. At one company, the shift schedule also comprised day shifts (4-shift system). Except for the semi-continuous shift systems, the shift schedules involved work during the weekends (Saturday and Sunday). Based on the six ergonomic criteria presented in the introduction, eight shift schedule characteristics were constructed (Table 5.1). The criterion to provide adequate time to recover between two shifts was split into two characteristics: maximum number of days off before the night shift and the minimum of days off after the night shift. The night shift was chosen, because it is the most demanding shift and, in our study, most shift cycles ended with night shifts. A characteristic about the average hours worked per week was added. The cut-off values and reference categories for the shift schedule characteristics were based on scientific literature (16) and experts in the field of ergonomic scheduling.

Table 5.1. Shift schedule characteristics

Roster characteristic	Description	Cut-off
Consecutive shifts	Maximum number of consecutive shifts within a shift cycle	≤2; 3-4 (reference); ≥5
Early starts	Start time of the morning shift	<7:00h; ≥7:00h (reference)
Consecutive working days	Maximum number of consecutive working days within a shift cycle	≤5 (reference); ≥6
Direction of rotation	Direction of rotation	Forward (reference); Backward
Weekends off*	Number of weekends off per year	≤10.4; >10.4 (reference)
Recovery days	Minimum numbers of days off after a night shift within a shift cycle	≤2; 3 (reference); ≥4
Rest days	Maximum number of days off before a night shift within a shift cycle	<1; ≥1 (reference)
Hours worked per week	Average number of working hours per week, without holidays	≤35 (reference); >35

* Weekend off is defined as not working on Saturday and Sunday. A night shift starting on Friday is considered as working on Saturday, a night shift starting on Sunday is considered as working on Monday

Shift-specific outcomes were assessed separately for the morning, evening and night shift, while generic outcome measures were assessed overall.

Shift-specific outcome measures

Sleep quality was assessed with the Karolinska Sleep Questionnaire (KSQ), containing seven items combined in two indices: Disturbed Sleep Index (DSI) and Awakenings complaints Index (AwI), with higher scores indicating worse sleep quality (22, 23). The response categories were: '1: Never, 2: Almost never, 3: Sometimes (once or more per month), 4: Mostly (once or more per week), and 5: Always (almost every day)'. The Disturbed Sleep Index was constructed by averaging scores on the items (i) difficulties falling asleep, (ii) disturbed/restless sleep, (iii) repeated awakenings, (iv) premature awakenings. The Awakenings complaints Index was constructed by averaging the scores on the items (i) difficulties waking up, (ii) non-refreshing sleep, and (iii) exhausted at awakening.

Need for recovery (NFR) is part of the Dutch Questionnaire on Perception and Judgement of Work (VBBA) (24, 25). The need for recovery scale contains 11 statements with dichotomous responses (yes/no), reflecting the immediate need for recovery after coming home from work (25, 26). The responses were summed and transformed into a range of 0-100, with higher scores indicating a higher need for recovery.

Generic outcome measures

Fatigue was assessed with the 8-item subscale 'prolonged fatigue' of the Checklist Individual Strength (CIS-8) (27-29). Respondents were asked to indicate on a 7-point Likert scale their agreement with 8 statements ('Yes, that is true' to 'No, that is not true'), resulting in a sum score of 8-56, with higher scores indicating higher fatigue levels.

Health status was measured with the Short-Form 12 (SF-12) (30). Mental and physical component scores were calculated. The SF-12 is a reliable and widely used instrument and is constructed as such that an average person in the United States scores 50 points (51 in the Netherlands (31)), with higher scores indicating better health.

Performance was operationalized as work functioning and assessed with the Dutch version of the Work Role Functioning Questionnaire (WRFQ-DV) (32). The WRFQ contains 27 items measuring the perceived difficulties of meeting work demands due to workers' physical health or emotional problems. Higher scores indicate better work functioning.

Statistical analysis

Only participants with complete data were used for the analyses. Differences between participants with complete and incomplete data were tested with independent samples t-test and Mann Whitney U-test. Associations between ergonomic criteria and health and work functioning were tested in a multilevel linear regression analyses adjusted for age, gender and care for children. The ergonomic criteria were tested separately (Model 1) and combined (Model 2). To avoid collinearity problems, ergonomic criteria with a variance inflation factor of more than 5 were excluded from the combined analyses (Model 2) (33). Four ergonomic criteria had a variation inflation factor larger than five and were excluded from the multivariate analyses due to collinearity, resulting in four ergonomic criteria included in the final model (Model 2): consecutive shifts, early starts, recovery days and hours worked per week. Two levels were incorporated in the multilevel analyses: workers nested in departments. Multilevel linear regressions were estimated in SAS 9.3, using the Huber/White estimator for the variance-covariance matrix of the fixed-effects parameters. This estimator is commonly referred to as the "sandwich" estimator, and provides robust standard errors in presence of non-normality (34). All other analyses were conducted with SPSS version 20.0 (35).

Table 5.2. Study sample descriptives (N=441)

	N	%		Mean	SD	N	%
Shift schedule characteristics			*Outcome measures**				
Consecutive shifts			Disturbed sleep index (M)	2.35	0.98		
3-4	98	22.22	Disturbed sleep index (E)	1.87	0.80		
≤2	290	65.76	Disturbed sleep index (N)	2.39	0.99		
≥5	53	12.02	Awakening complaints index (M)	2.62	1.04		
Early starts			Awakening complaints index (E)	1.95	0.84		
≥7:00h	350	79.37	Awakening complaints index (N)	2.56	0.98		
<7:00h	91	20.63	Need for recovery (M)	31.18	28.17		
Consecutive working days			Need for recovery (E)	15.96	21.89		
≤5	144	32.65	Need for recovery (N)	41.03	31.23		
≥6	297	67.35	Fatigue	22.58	10.88		
Direction of rotation			Mental health	50.73	8.52		
Forward	377	85.49	Physical health	50.51	7.19		
Backward	64	14.51	Work functioning	86.65	13,71		
Weekends off*							
>10.4	164	37.19	*Covariates*				
≤10.4	277	62.81	Age	44.81	8.67		
Recovery days			Gender				
'3	77	17.46	Male			411	93.20
≤2	80	18.14	Female			30	6.80
≥4	284	64.40	Care for children				
Rest days			Yes			274	62,13
≥1	144	32.65	No			167	37,87
<1	297	67.35					
Hours worked per week							
≤35	375	85.03					
>35	66	14.97					

* Scale ranges Disturbed Sleep Index and Awakening complaints Index: 1-5, Fatigue: 8-56, Need for recovery, Mental health, Physical health and Work functioning: 0-100.

Results

Study sample descriptives

In total N=551 (response 61%) shift workers returned the questionnaire. Only participants with complete data were used for analyses, resulting in a final study sample of N=441 (49%) shift workers. The analyses between participants with complete and incomplete data revealed that excluded shift workers with missing items were significantly older compared to the final study sample (mean 47.51 vs. 44.81 years of age). For all other measures, no differences were found between participants with complete and incomplete data.

The mean age of the study sample was 44.81 years (SD 8.67). The majority of their working life they were working shifts (mean 20.30 years, SD 9.28) and on average they were employed by their current employer for 16.77 years (SD 9.70). The vast majority was male (93.20%) and 62.13% had children to care for. Most male shift workers were employed as process operators, while most of the female shift workers were employed at an assembly line. An overview of the study sample descriptives is presented in Table 5.2.

Shift-specific outcome measures

Analysing the ergonomic shift schedule criteria separately resulted in ten associations with shift-specific sleep and recovery out of 72 possible associations (Table 5.3): for morning shifts: early start time (<7:00h), forward rotation, many weekends off and short weekly working hours; for evening shifts: many consecutive shifts, backward rotation and long weekly working hours were associated with more sleep and need for recovery complaints. No associations were found for night shifts and for 'consecutive working days', 'recovery days' and 'rest days'.

When analysing the ergonomic criteria combined in one model, five associations were found with more sleep and recovery complaints (Table 5.4): for morning shifts: many consecutive shifts, early start time (<7:00h) and short weekly working hours; for evening shifts: few consecutive shifts and long weekly working hours. Again, no associations were found for night shifts.

Generic outcome measures

When analysing the criteria separately, nine out of the possible 32 associations were found with generic health and work functioning measures (Table 5.5). Many consecutive shifts, many consecutive work days, few weekends off and no rest day before night shifts were associated with higher fatigue, lower physical health and lower work functioning. No associations were found for the shift schedule characteristics 'early starts', 'direction of rotation', 'recovery days' and hours worked per week with any of the outcome measures, or for any of the shift schedule characteristics with mental health. When combining the ergonomic shift schedule criteria into one model (model 2), only the association for two or less consecutive shifts with lower work functioning remained (borderline) significant (Table 5.6).

Table 5.3. Univariate multilevel analyses adjusted for age, gender and care for children (B=Beta, 95%CI = 95% Confidence Interval)

	Morning shift						Evening shift						Night shift					
	Disturbed sleep		Awakenings complaints		Need for recovery		Disturbed sleep		Awakenings complaints		Need for recovery		Disturbed sleep		Awakenings complaints		Need for recovery	
	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI
Consecutive shifts																		
3-4	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
≤2	-0.11	-0.37-0.16	-0.11	-0.4-0.17	-5.54	-9.58--1.5	0.06	-0.08-0.2	0.15	0-0.31	7.32	0.08-14.55	-0.11	-0.4-0.18	-0.08	-0.26-0.11	0.88	-6.74-8.5
≥5	-0.17	-0.43-0.08	0.15	-0.2-0.51	2.10	-10.03-14.24	0.43	0.2-0.66	0.46	0.19-0.73	6.88	-0.04-13.8	0.05	-0.34-0.44	0.07	-0.2-0.34	-0.02	-9.31-9.27
Early starts																		
≥7:00h	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
<7:00h	0.12	-0.13-0.37	0.21	-0.17-0.59	8.24	4.21-12.27	0.11	-0.08-0.3	0.11	-0.12-0.34	4.06	-9.65-17.76	0.13	-0.15-0.41	0.06	-0.16-0.28	-1.10	-10.56-8.36
Consecutive working days																		
≤5	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
≥6	0.19	-0.02-0.4	-0.07	-0.31-0.18	-0.80	-6.64-5.04	-0.04	-0.24-0.16	-0.04	-0.25-0.17	3.71	-3.1-10.52	-0.07	-0.33-0.2	-0.14	-0.33-0.05	2.19	-3.96-8.33
Direction of rotation																		
Forward	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
Backward	-0.23	-0.45-0	0.06	-0.29-0.42	4.90	-4.66-14.45	0.27	0.02-0.53	0.26	0.02-0.5	1.10	-4.74-6.95	-0.01	-0.33-0.32	0.12	-0.05-0.28	1.92	-4.13-7.98
Weekends off*																		
>10.4	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
≤10.4	0.02	-0.19-0.23	-0.04	-0.29-0.21	-6.32	-10.7--1.95	-0.16	-0.34-0.02	-0.07	-0.26-0.12	-1.44	-8.29-5.41	-0.13	-0.36-0.1	-0.07	-0.21-0.08	-0.30	-5.73-5.14
Recovery days																		
'3	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
≤2	0.04	-0.33-0.42	0.19	-0.26-0.64	6.88	-2.76-16.53	0.29	-0.03-0.61	0.14	-0.26-0.53	-3.20	-17.15-10.75	-0.12	-0.59-0.35	0.00	-0.36-0.35	-1.89	-14.14-10.36
≥4	0.27	-0.05-0.58	0.15	-0.22-0.52	2.10	-4.25-8.44	0.06	-0.19-0.32	-0.05	-0.37-0.28	-3.72	-17.66-10.21	-0.14	-0.56-0.27	-0.11	-0.43-0.22	0.02	-9.7-9.73
Rest days																		
≥1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
<1	0.19	-0.02-0.4	-0.07	-0.31-0.18	-0.80	-6.64-5.04	-0.04	-0.24-0.16	-0.04	-0.25-0.17	3.71	-3.1-10.52	-0.07	-0.33-0.2	-0.14	-0.33-0.05	2.19	-3.96-8.33
Hours worked per week																		
≤35	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
>35	-0.19	-0.36--0.01	-0.03	-0.47-0.41	5.98	-2.8-14.76	0.40	0.23-0.58	0.41	0.22-0.6	10.02	-2.31-22.34	0.12	-0.14-0.37	0.04	-0.16-0.25	1.89	-4.12-7.9

Table 5.4. Multivariate multilevel analyses adjusted for age, gender and care for children (B=Beta, 95%CI = 95% Confidence Interval)

	Morning shift						Evening shift						Night shift					
	Disturbed sleep		Awakenings complaints		Need for recovery		Disturbed sleep		Awakenings complaints		Need for recovery		Disturbed sleep		Awakenings complaints		Need for recovery	
	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI	B	95%CI
Consecutive shifts																		
3-4	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
≤2	-0.12	-0.47-0.22	0.08	-0.26-0.43	-5.74	-15.19-3.72	-0.01	-0.3-0.27	0.16	-0.11-0.44	2.95	-5.25-11.14	-0.17	-0.63-0.28	0.02	-0.3-0.35	-3.59	-14.15-6.98
≥5	0.58	-0.34-1.5	1.71	0.79-2.63	-0.16	-25.62-25.3	-0.17	-0.91-0.57	-0.04	-0.78-0.7	-35.10	-56.46--13.74	0.41	-0.75-1.58	0.57	-0.3-1.45	-14.18	-42.62-14.26
Early starts																		
≥7:00h	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
<7:00h	0.26	-0.09-0.61	0.52	0.17-0.87	5.91	-3.77-15.59	-0.01	-0.3-0.27	0.08	-0.21-0.36	-3.10	-11.3-5.11	0.11	-0.34-0.56	0.10	-0.23-0.43	-4.40	-15.22-6.41
Recovery days																		
'3	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
≤2	-0.23	-0.72-0.25	-0.32	-0.80-0.16	0.67	-12.65-14	0.14	-0.25-0.53	0.04	-0.35-0.43	3.66	-7.66-14.98	-0.47	-1.09-0.15	-0.17	-0.62-0.29	-1.51	-16.39-13.37
≥4	0.29	-0.02-0.59	0.05	-0.25-0.35	6.26	-2.08-14.6	0.18	-0.07-0.43	0.02	-0.22-0.26	3.42	-3.84-10.67	-0.10	-0.51-0.31	-0.16	-0.44-0.13	2.64	-6.68-11.96
Hours worked per week																		
≤35	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
>35	-0.43	-1.16-0.3	-1.22	-1.95--0.49	4.96	-15.25-25.17	0.57	-0.02-1.16	0.48	-0.11-1.07	41.06	24.12-58	-0.05	-0.97-0.87	-0.43	-1.12-0.26	15.69	-6.89-38.27

Table 5.5. Univariate multilevel analyses adjusted for age, gender and care for children (B=Beta, 95%CI = 95% Confidence Interval)

	Fatigue		Mental health		Physical health		Work functioning	
	B	95% CI	B	95% CI	B	95% CI	B	95% CI
Consecutive shifts								
3-4	0.00							
≤2	3.71	1.59-5.83	-1.11	-2.82-0.6	-1.93	-3.64--0.22	-3.95	-6.15--1.75
≥5	3.83	1.6-6.06	-0.24	-3.15-2.67	-0.54	-2.51-1.43	-1.08	-5.33-3.17
Early starts								
≥7:00h	0.00		0.00		0.00		0.00	
<7:00h	-1.90	-4.33-0.52	1.05	-0.92-3.03	0.36	-1.82-2.54	1.24	-1.49-3.98
Consecutive working days								
≤5	0.00		0.00		0.00		0.00	
≥6	2.12	-0.13-4.37	-1.11	-2.89-0.68	-1.85	-3.32--0.38	-2.86	-5.46--0.26
Direction of rotation								
Forward	0.00		0.00		0.00		0.00	
Backward	1.76	-0.18-3.7	0.37	-1.6-2.34	0.75	-0.62-2.12	0.97	-2.65-4.59
Weekends off*								
>10.4	0.00		0.00		0.00		0.00	
≤10.4	2.26	0.25-4.27	-0.71	-2.14-0.73	-1.24	-2.76-0.28	-3.20	-5.53--0.87
Recovery days								
'3	0.00		0.00		0.00		0.00	
≤2	1.64	-2-5.27	1.41	-1.74-4.57	0.53	-1.85-2.92	-0.30	-4.34-3.74
≥4	2.51	-0.07-5.1	-0.10	-2.46-2.27	-1.04	-3.43-1.36	-2.59	-5.94-0.75
Rest days								
≥1	0.00		0.00		0.00		0.00	
<1	2.12	-0.13-4.37	-1.11	-2.89-0.68	-1.85	-3.32--0.38	-2.86	-5.46--0.26
Hours worked per week								
≤35	0.00		0.00		0.00		0.00	
>35	1.45	-0.36-3.26	-0.10	-2.29-2.08	-0.07	-1.96-1.82	0.90	-2.71-4.52

Table 5.6. Multivariate multilevel analyses adjusted for age, gender and care for children (B=Beta, 95%CI = 95% Confidence Interval)

	Fatigue		Mental health		Physical health		Work functioning	
	B	95% CI	B	95% CI	B	95% CI	B	95% CI
Consecutive shifts								
3-4	0,00		0,00		0,00		0,00	
≤2	2,65	-0,96-6,25	0,41	-2,47-3,28	-1,18	-4,16-1,8	-4,60	-9,21-0
≥5	-0,32	-10,03-9,39	2,24	-5,5-9,98	2,40	-5,25-10,06	1,59	-10,81-14
Early starts								
≥7:00h	0,00		0,00		0,00		0,00	
<7:00h	-0,95	-4,64-2,74	1,34	-1,61-4,28	-0,05	-3-2,9	-1,30	-6,02-3,41
Recovery days								
'3	0,00		0,00		0,00		0,00	
≤2	2,05	-3,03-7,13	1,69	-2,36-5,74	-0,19	-4,27-3,89	-3,19	-9,68-3,3
≥4	2,15	-1,03-5,33	-0,51	-3,05-2,02	-1,39	-4,03-1,25	-1,69	-5,75-2,38
Hours worked per week								
≤35	0,00		0,00		0,00		0,00	
>35	3,38	-4,33-11,08	-3,72	-9,87-2,42	-3,32	-9,39-2,75	-1,19	-11,04-8,66

Discussion

The aim of this study was to examine associations between shift schedule characteristics and shift-specific sleep and need for recovery and generic health and performance measures. Eight shift schedule characteristics were constructed based on existing ergonomic recommendations (17). The shift schedule characteristics were analyzed separately and combined in one model in relation to sleep, need for recovery, health and performance measures. The hypothesis that shift schedules meeting the ergonomic criteria are associated with better sleep, need for recovery, health and work functioning was largely not confirmed. Relatively few associations were found, of which the majority was in the direction as expected. Although some associations were found when analyzing the characteristics separately, only a few associations remained significant when combining the shift schedule characteristics in one model.

When analyzing the shift schedule characteristics separately (Model 1), most significant associations were in line with previous research. Among those associations in line with previous research, most associations were found for the number of consecutive shifts and the number of consecutive working days. Similar to the reviews of Knauth and Hornberger (17) and of Sallinen and Kecklund (15), very few (≤2) or many (≥5) consecutive shifts and many consecutive working days (≥6) were found to be detrimental for sleep, need for recovery, fatigue, physical health and work functioning. In addition to literature showing an association between starting time of morning shifts and awakening complaints (36, 37), in the present study a higher need for recovery was found when starting morning shifts before 7:00 o'clock. In contrast to earlier research, inconsistent results were found in Model 1 for the direction of rotation, number of weekends off and weekly working hours. Backwards rotation was associated with less disturbed sleep for morning shifts, but more disturbed sleep and awakenings complaints for evening shifts. In general, forward rotation is favored by shift workers (15, 16, 38, 39), although a well-controlled intervention study found an improvement in sleep quality when changing from a fast forward rotating schedule to a slowly backwards rotating schedule (40). In our study, less disturbed sleep for morning shifts for workers in backwards rotating schedules might also be due to the starting time of morning shifts. Three out of four companies using a backwards rotating schedule started the morning shift at 7:00 o'clock. Also non-included factors (e.g. work demands) might explain the counterintuitive findings.

Concerning the annual weekends off, fewer weekends off was associated with lower need for recovery for morning shifts, but also more fatigue and lower work functioning. To maximize time for social activities, recovery is better during Saturday and Sunday compared to midweek days off (20). However, for shift workers weekends do not necessarily pertain to Saturday and Sunday as shift workers use irregular shift schedules to increase time for family activities (41, 42). Moreover, in our study sample all workers with ≤10.4 annual weekends off started the morning shift at 7:00 o'clock, which might explain their lower need for recovery for morning shifts. The higher fatigue and lower work functioning might be a result of few annual weekends off in combination with many consecutive working days. The vast majority of workers with ≤10.4 annual weekends off worked ≥6 consecutive days.

The last characteristic with inconsistent findings in the separate analyses (Model 1) was the average weekly working hours. Working >35 hours per week was associated with less disturbed sleep for morning shifts and more disturbed sleep and awakening complaints for evening shifts. Working long hours is generally accepted as a risk factor for sleep disturbances and health (43, 44). A possible explanation for these contradictory results might be that in this study the average weekly working hours were relatively low, ranging from 33.6 to 40.0 hours. As in the Netherlands the average weekly working hours are lower compared to e.g. the United States and Asian countries (45), other factors might be more influential. Studies examining the relation between weekly working hours and health define long weekly working hours as working more than 55 hours per week (44).

Only four out of eight shift schedule characteristics were included in the combined analyses (Model 2), showing both similar and divergent results compared to previous research. In line with earlier research was the finding of more awakening complaints when starting the morning shift before 7:00 o'clock (36, 37, 46). Even when other shift schedule characteristics were included in the analysis, the timing of the morning shifts was associated with shift-specific sleep for morning shifts. Workers do not proportionally change their bed time according to the start of the morning shift (47), feeling less refreshed upon awakening. For

example, watching late night shows may conflict with the opportunity to sleep (48).
In the combined analyses mixed results were found concerning the number of consecutive shifts and the weekly working hours. Working ≥6 consecutive shifts was associated with more awakening complaints for morning shifts and lower need for recovery for evening shifts. Working >35 hours per week was associated with less awakening complaints for morning shifts and higher need for recovery for evening shifts. In the present study the weekly working hours are closely related to the number of consecutive shifts, which can be illustrated by the type of shift system. Shift workers working >35 hours per week are mainly working in semi-continuous shift systems with slowly backwards rotating shift schedules involving alternating five consecutive shifts (Appendix 5.A). Shift workers working ≤35 hours per week are mainly working in continuous shift systems with a maximum of four consecutive shifts. Although the included ergonomic criteria in the combined model (Model 2, Table 5.4) adhered to a variation inflation factor threshold lower than five, co-occurrence of the characteristics the number of consecutive shifts and the average weekly working hours might still have caused collinearity issues. The results concerning these two criteria in the combined model should therefore be interpreted with caution.
As stated earlier, relatively few significant associations were found considering the number of statistical tests. In case associations were significant, the effect sizes seemed to be relatively small. Both observations might be due to a relatively healthy population and limited variability between the included shift schedules. First, our study sample is relatively healthy and shows similar scores on health and work functioning compared to other healthy Dutch worker populations (29, 31, 49). The healthy worker effect might have occurred, i.e. a selection process leaving only those best fit for shift work (50). Workers who consider themselves incapable of doing shift work choose not to enroll in a shift work job, while shift workers who develop health problems leave shift work for a daytime job. Both will result in a relatively healthy shift work population, resulting in limited variation in health and work functioning to detect differences. Second, shift workers in our study might already have been quite satisfied with their schedules. The majority of the included schedules adhered to the ergonomic recommendations (16) and extreme schedules (e.g. >5 consecutive night shifts) were absent. Therefore, the variation between the schedules might have been too small to detect associations with health and work functioning with the current sample size.
Among the nonsignificant findings, some interesting results can be observed as well. First, no associations were found for night shifts, commonly acknowledged as the most burdening shift. The absence of extreme differences in the number of consecutive night shifts might have attributed to the finding of no associations. Another explanation might be that night shifts are burdening to all workers. There are indications that the individual variability for sleep quality and need for recovery is higher for morning shifts, compared to night shifts (7, 51). Yet, in our study most associations have been found for evening shifts, which generally is least affected by individual variability in sleep and need for recovery. Evening shifts might

be more burdening than generally acknowledged, although considering the large number of tests also Type I errors cannot be excluded. Second, in line with earlier research (52, 53) no associations were found with mental health. So far, the effects of shift work on mental health have only been scarcely studied and not well understood, warranting further research.

Strengths and limitations

The main strength of this study is that several shift schedule characteristics were combined in one study sample using the same outcome measures. It is virtually impossible to adhere to all criteria. Adhering to one criterion can compromise other criteria, thereby counterbalancing positive and negative effects in the long term. For example, limiting the number of consecutive night shifts will also limit the number of recovery days after a night shift. Combining several shift schedule characteristics into one model might provide insight which characteristics matter most. Due to limited variability in shift schedules, only four shift schedule characteristics could be included in the combined model. The response rate can be considered as reasonable, even taken into account the number of missing items (54). The analyses between cases with and without missing items revealed only a difference for age. A limitation of this study is the limited variation between the included schedules, resulting in only four out of eight shift schedule characteristics in the multivariate analysis. The vast majority of the included schedules were regular 3-shift systems with 7-9 hour shifts. Our results are therefore not necessarily generalizable to other regular shift systems, e.g. extreme shift systems common in offshore or mining. It would be interesting to also include these extreme shift systems to be able to compare a larger variety of shift schedules and shift schedule characteristics. The inclusion of extreme shift systems will probably show larger effects on all examined outcomes. Yet, workers in extreme shift systems often have to fly in and out of the work site. Due to the large distances, these extreme shift systems are designed to maximize time to work while being on-site to provide more time for family and social life off-site. Next to different effects for physical and mental outcomes, also larger differences may be expected for social well-being. Unfortunately, no outcomes related to social well-being were incorporated. Shift workers' attitude towards a schedule also depends on the ability to organize social life in conjunction with the schedule. For some of the ergonomic criteria, stronger effects might have been obtained with work-family interference. Next to the limited variation in shift schedules, this study was limited by the cross-sectional design. It might well be that shift schedule recommendations are more strongly related to health development over time. A longitudinal study using a similar design (i.e. including several shift schedules) is greatly needed to examine the separate and relative contribution of shift schedule characteristics to the development of health and work functioning over time. Another limitation is that the study does not adjust for the influence of other factors that also play a role for shift work problems. For example, differences in socioeconomic status, work environment exposure, work-non-work balance, health-related behaviors (life-style) and commuting time between the schedules might have masked some of the "true" effect of shift scheduling. Still little is known about the relative contribution of shift work and work-related characteristics in the development of health-related complaints. Related to the previous comment, including objective measures of health and wellbeing next to subjective measures might strengthen the results. Furthermore, as the study sample comprised mostly male industrial workers, the results are not necessarily generalizable to other occupational groups or female workers. Traditional family roles may lead to different effects for male and female workers. For example, nonstandard schedules resulted in greater relationship dissatisfaction in women, compared to men (41), while for fathers nonstandard schedules increased the involvement in caregiving and joint family activities (42).

Implications for research and practice

Finding only a few associations for shift schedule characteristics with work and health outcomes in already ergonomically well-designed shift schedules might imply that there is only little room for improvement. Still, some shift schedule characteristics might be more important than others. Early morning shifts and many consecutive shifts and working days should be avoided. Not only were most associations found for these three characteristics, they might also have played a role in explaining the counterintuitive findings for the shift schedule characteristics 'direction of rotation' and 'number of annual weekends off'. For slowly backwards rotating shift schedules (e.g. NNNNNxxEEEEExxMMMMMxx) very irregular shift schedules would be designed when restricting the number of consecutive shifts to 2-3 and the number of consecutive working days to 3-4. Yet, for fast forward rotating shift schedules it might be worthwhile to investigate the effects of incorporating a rest day before the night shift (e.g. MMEExNNxxx instead of MMEENNxxxx). More research is warranted to test these assumptions, preferably in a larger and more heterogeneous sample with more variation in the included shift schedules. Furthermore, there is a need for adjusting for a wider variety of confounders and using a longitudinal design.

Conclusion

In conclusion, shift schedules meeting the ergonomic criteria for at least some of the schedule characteristics show weak but largely positive associations with shift-specific sleep and need for recovery and generic health and performance outcomes. The few associations found confirm that early starts of the morning shift should be avoided, even when controlled for other shift schedule characteristics. Furthermore, the results suggest that continuous fast forward-rotating schedules might benefit from fitting in a rest day before the night shift. Longitudinal studies, preferably in combination with work-related factors, are needed to disentangle the relation between shift schedule characteristics with sleep, need for recovery, health and performance.

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CHAPTER 8

General discussion

General discussion

The overall aim of the 'Shift Your Work' study was to contribute to a better understanding of sustainable employability of older shift workers by implementing new shift systems. This aim was derived from two initial premises: 1) shift work becomes more burdening with older age, and 2) sustainable employability can be enhanced by implementing new shift systems. These premises were examined in two parts, in which no convincing evidence was found either supporting or opposing the two premises. In Part I, hardly any age-related effects were found. In comparison with age, chronotype seemed to better explain individual differences in sleep and need for recovery. Even though in Part II a few positive associations for the design of a shift system with health, work functioning and social life were found, the evidence was weak and new shift systems deemed hard to be implemented.

In this chapter, the findings of the 'Shift Your Work' study will be discussed in view of the scientific literature and environmental and societal trends. Methodological considerations will be addressed and the chapter will be concluded with implications and challenges for research and practice.

Part I: The ageing shift worker

In Part I three studies were conducted to examine the effects of shift work on outcomes related to sustainable employability within different shift systems, with a special focus on age.

Main findings

In Chapter 2 individual and work-related predictors of shift work exit were examined among older and younger male shift and day workers. Shift work exit was operationalized as temporarily being placed in less strenuous work, long-term sickness absence and leaving the organization. Earlier studies already showed that adverse health effects of shift works did not lead to more sickness absence or higher risk of leaving the organization for shift workers compared to day workers (1, 2). Our study adds that also the predictors of shift work exit do not seem to differ in direction and magnitude, neither between shift and day workers, nor between older and younger shift workers.

In Chapter 3 we examined associations of chronotype and age with shift-specific assessments of sleep duration, sleep quality and need for recovery. There are indications that sleep problems and need for recovery increase with increasing age (3-5). Yet, in line with previous research (6), we only found associations for chronotype and not for age. Compared to early chronotypes, late chronotypes reported shorter sleep duration and more awakening complaints during morning shifts. No associations were found for evening and night shifts.

In Chapter 4 we investigated need for recovery among male technical distal on-call workers. Distal on-call work refers to a working time arrangement in which workers during on-call periods may stay at home and can be called back to the workplace in case of an emergency. According to Dutch working time legislation, distal on-call work is considered resting time (7). Levels of need for recovery when on-call were similar compared to morning shift periods and 1.5-2 times higher compared to regular working periods, even when workers were not called during an on-call period. Furthermore, we found associations for higher need for recovery with lower scores of sleep quality and mental health symptoms and higher scores of fatigue, work demands and work-family interference. In this chapter too, we found no differences for older compared to younger workers.

Reflections on findings Part I

The main results of the three studies in Part I showing no age-related effects are in line with the inconclusive evidence summarized by two earlier reviews (8, 9), questioning whether policies and interventions should be specifically aimed at older shift workers. Yet, research findings in the general (working) population and observations during the 'Shift Your Work' study (e.g. conversations with shift workers and their supervisors and occupational physicians) do suggest that shift work becomes more burdening with increasing age.

The premise that shift work becomes more burdening with older age builds upon the adverse health-effects of shift work in combination with health deterioration and increasing vulnerability when physiologically ageing (10-12). A meta-analysis in the general population of healthy participants aged 5 to 102 years old showed decreasing sleep length and efficiency with increasing age (3). In combination with earlier phasing of the circadian clock (13), this may provide an explanation why in particular older shift workers seem to have more difficulties with night shifts (8). Research in the general working population has shown that with increasing age need for recovery increases (4, 5), chronic diseases are more prevalent (14, 15) and sickness absent spells last longer, although older workers are less frequently absent from work (16). Shift work in turn is associated with an increased risk of developing sleep problems and chronic diseases (17-19). Yet, at the intersection of shift work and age evidence is lacking and we did not find age-related differences in sleep, need for recovery and predictors of sickness absence either. Several possible explanation for the null-findings of age-related effects may apply.

It may be that other characteristics than age better explain individual differences in outcomes related to sustainable employability. We did not find associations for age with shift-specific assessments of sleep duration and quality and need for recovery, but in congruence with other studies (6, 20) we did find decreased sleep duration and sleep quality for late compared to early chronotypes during morning shifts. Chronotype is age dependent, showing a later orientation in adolescents shifting towards an earlier orientation with increasing age (21, 22). However, a very late chronotype will never become a very early chronotype. Chronotype might therefore be an important concept to explain age-related differences in immediate outcomes, like sleep and need for recovery. Yet, associations of chronotype and general outcomes measures (i.e. non shift-specific measures like general health, performance and work-family conflict) are less well established, showing positive associations for both early and late chronotypes or no associations at all (9). Perhaps, differences in sleep duration and sleep quality between early and late chronotypes for morning and night shifts might counterbalance each other, resulting in inconclusive results for these general outcome measures. Another reason for only few to no age-related effects might be the healthy worker effect. The healthy worker effect refers to that those workers best fit for and able to adapt to work will be selected for and stay at work (23). There are two indications of a healthy worker effect in our study; 1) similar scores of our study sample on health, work functioning and work-family balance compared to other healthy work populations (5, 24-26) and 2) the relatively few older shift workers. The healthy worker effect is difficult to assess due to logistical and time-based constraints. There is some evidence of selection into shift work (27). In concurrence with other studies, we did not find evidence for selection out of shift work (1, 28). The Dutch tendency to favor regulations to "spare" older workers (29, 30) might have veiled selection out of shift work. Amongst traditional age-based human relation policies (e.g. training, demotion, accommodation and early retirement), early retirement was most common in the Netherlands. Return on investment of training older workers is considered limited (31), demotion might have an adverse impact on employee satisfaction and productivity (32), and in the industrial sector examples of accommodation in terms of part-time employment or individualized schedules are scarce.

Next to selection effects, the healthy worker effect also includes adaptation strategies. The industrial shift workers included in Part I have been working in shifts for the vast majority of their working life. Over time, initial effects might have played themselves out. Adaptation strategies can be developed to minimize the adverse effects of shift work and may become more effective with increasing age. A well-known adaptation strategy is taking a nap to minimize accumulation of sleep loss, e.g. early chronotypes take naps of up to three hours before night shifts to compensate for anticipated sleep loss (33). In Chapter 3, about one third of the shift workers reports to nap after morning shifts or before night shifts. Another example of an adaptation strategy is to use the advantages of shift work to reorganize family life, e.g. tag-team parenting to avoid childcare (34). In the Netherlands, parent child interaction is at least equal, if not more, for shift workers compared to day workers, in particular for male shift workers (35). These mechanisms might especially play a role in the, male dominated, industrial sector.

Part II: Enhancing sustainable shift work employability by implementing new shift systems?

The three studies of Part II investigated the design of a shift system, in particular the process towards implementing new shift systems, and its effects on health, work functioning and social life.

Main findings

The focus in Chapter 5 was on the design of the shift system. We examined among a large

number of shift schedules associations between eight on ergonomic criteria based shift schedule characteristics (36) and sleep, need for recovery, fatigue, health and work functioning. These eight criteria comprised the 1) number of consecutive shifts, 2) start time of the morning shift, 3) number of consecutive working days, 4) direction of rotation, 5) number of annual weekends off, 6) number of recovery days, 7) number of rest days before a night shift and 8) average weekly working hours. We only found a few significant associations, of which the majority was in support of ergonomic shift scheduling recommendations.
In Chapter 6, we examined facilitators and barriers for the implementation of a new shift system. Interviews were conducted among production managers, trade unions and workers of six companies, of which three companies successfully implemented a new shift system and three companies cancelled the implementation. We identified framing the intervention in terms of production benefits, or at least no losses, as a facilitating factor. Barriers were alterations of current employment terms and involvement of headquarters and trade unions.
In Chapter 7 we examined the influence of workers' attitude towards a shift system change and changes in health, work ability, work functioning and work-family interference after implementation of a new shift system. The study was conducted among five different organizations, which implemented a new shift system due to various reasons (e.g. to enhance sustainable employability). We found that a positive attitude of workers towards a new shift system before implementation was prospectively associated with a decrease in mental health symptoms and an increase in work ability and work-family balance after implementation.

Reflections on findings Part II
The implementation of new shift systems to enhance sustainable employability deemed to be challenging. New shift systems have a large impact on workers and organizations. For shift workers a new shift system may affect the distribution of free days and the financial compensation for working in shifts. Organizations need to arrange a transition period and possibly reconfigure the skillset of their workforce. In our study the sense of urgency to change might have been low due to a relatively healthy population, ergonomically already sound shift schedules and the economic crisis. When implementing a new shift system, the process towards implementations seemed to be as important as the design of the shift system.
A key concept in change management is creating a sense of urgency (37). A relatively healthy study population, shift schedules adhering to the ergonomic recommendations of a fast forward rotating shift schedule (36, 38-41) and the absence of extreme shift schedules (e.g. > 5 consecutive night shifts) might have led to a low sense of urgency to implement new shift systems in in the organizations in our study. The small variety in shift schedules in combination with a relatively healthy population might explain why we only found a few associations with small effect sizes for shift schedule characteristics with the outcomes health and work functioning. In addition, the 'Shift Your Work" study was conducted during the

worldwide economic crisis lasting from roughly 2008 to 2012. During times of economic recession, interventions aiming to enhance sustainable employability might be hard to implement. Organizations prioritize activities in accordance with immediate threats of survival and sustainable employability efforts may seem inappropriate in a period of downsizing in personnel.

Other key concepts of change management are stakeholder involvement, creating a vision and removing obstacles (37). Our results are in line with these key concepts, showing the importance of timely involvement of stakeholders and management vision, while concerns about changing current employment terms was an important obstacle to resolve. The financial compensation is an important reason for working in shifts. Depending on the shift schedule, financial benefits might mount up to an extra 30% on top of a shift worker's salary. A change in working hours may imply a change in benefits, which might possibly lead to suspicion among workers about the real reasons for implementing a new shift system. Therefore shift systems fitting in current employment terms were more likely to get implemented. The process prior to implementation may not only affect the success of implementation, but also how the new shift system will be evaluated by workers. Not adequately managing the change process might lead to resistance to change. We have found a direct relationship between a positive attitude towards the new shift system intervention and improvement in health, work functioning and work-family balances after the intervention (Chapter 7). Organizations seem to be aware of the impact and complexity of implementing a new shift system and might therefore choose to focus rather on more universal sustainable employability efforts, e.g. optimizing the work environment, providing individual accommodations, enhancing communication between workers and their supervisors or delivering health promotion (42-44).

As shown in the previous paragraphs, implementing new shift systems demands major efforts, while health-effects for changing already sound ergonomic schedule are expected to be small. Nevertheless, these considerations do not imply that shift system interventions cannot be used to enhance sustainable employability of shift workers. For shift systems not adhering to ergonomic recommendations, still considerable health gains can be achieved. Several intervention studies have shown positive effects when changing from a slowly backwards rotating schedule towards a fast forward rotating schedule (38-41). The importance of morning shifts starting after 7:00h were confirmed in our multivariate analyses and we found suggestive evidence of beneficial effects on health and work functioning of incorporating a rest day before the night shift (Chapter 7). The incorporation of a rest day before the night shift might be an interesting opportunity to further fine-tune already sound ergonomic shift systems. Compared to more rigorous changes, the expected benefits of fine-tuning are probably small. However, the impact on the organization and workers will also be small and will most likely fit employment terms.

General methodological considerations

Several methodological considerations specifically for Part I and Part II have already been presented in the specific study parts. In this section, general methodological considerations concerning the operationalization of sustainable employability, the design of the project and the study sample will be discussed.

Our operationalization of sustainable employability was inspired by the definition of van der Klink et al. (45), including health and work functioning as important aspects of sustainable employability. Our outcome measures reflected short-term effects (shift-specific sleep duration and sleep quality, and need for recovery), intermediate effects (general health, fatigue and work functioning), and long-term effects (sickness absence). Some concepts may have been understudied. Work- and social-related factors have only been accounted for in three studies in this thesis. Other factors related to sustainable employability of shift workers, like personal characteristics next to age and chronotype (e.g. genetics, flexibility of sleep habits, hardiness, lifestyle and skills) (9, 46), knowledge and skills (47) and the value of work (45), have not been included. Still little is known about the relative and combined effects of irregular working times and work, personal and social characteristics. For example, work-related factors like work demands and autonomy may be equally, or even more, important than night work exposure in relation to sleep and fatigue (48, 49). Besides, like the majority of shift work studies (19), the studies in this thesis had either a cross-sectional design or a limited time frame. Both designs cannot rule out a healthy worker effect as selection into and out of shift work was taken into account (50). Moreover, sustainable employability may change and evolve with age or life phase.

The 'Shift Your Work' study was set-up in two parts. The results of Part I were used as a need assessment to discuss the need and possibilities to design, implement and evaluate new shift systems in Part II. As discussed in the reflections on Part II, implementing new shift systems to enhance sustainable employability deemed to be challenging. During the research period, the focus of the study shifted slightly from the design of a new shift system towards the process prior to implementation. A more pragmatic approach was chosen to evaluate five already planned shift system changes. Because four out of five shift system changes originated in changed production volumes, other contextual factors might have influenced the evaluation. For example, in Chapter 7 large differences were found in the response rate. In feedback sessions, shift workers reported that the low response rate was probably due to framing economically needed shift system interventions in sustainable employability efforts. Selection bias is likely; only those in favor or against a shift system change may find it worthwhile to participate in the effect evaluation.

Another methodological consideration is the specific study sample. Although the 'Shift Your Work' project had a specific focus on age, it was decided for reasons of uniformity and in close collaboration with the participating organizations to include workers of all ages. Although the age distribution of our study sample resembled that of the study population of the organizations, targeting all workers might have caused that relatively few shift workers of 55 years and older were included. The lack of older workers in the study sample may also be due to policies "sparing" older shift workers. Most of these policies are now abandoned, meaning shift workers need to overcome the additional working years of the abandoned "sparing" policies and the increase in retirement age. Next, despite variation in companies and shift schedules, only industrial, predominantly male, workers from mostly large multinationals working in regular collective shift schedules were included in the separate studies. This implies that the results of this study are not generalizable to other sectors or shift systems. For example, the healthcare sector is characterized by female workers, working in irregular shift systems in which part-time work is more prevalent. Some studies have shown gender differences in the effects of shift work (51, 52), and also the number of work hours may affect health outcomes (44). Besides, large companies generally have more resources to facilitate sustainable employability, thereby limiting the generalizability for small to medium enterprises.

Implications and challenges for research

The implications and challenges for research deduced from the findings of this thesis are grouped in three themes. First, unresolved and emerged issues warranting further research are discussed. Second, challenges concerning pragmatic issues of work-based intervention research are discussed and alternative pathways are provided. Third, a call is made for a more integral approach when conducting shift work research.

Unresolved and emerged issues concerning sustainable employability of shift workers

- Considering the age distribution of shift workers in this thesis, many shift workers are at the verge of working past the initial early retirement age of 63 years. These additional working years are real years, due to the abolishment of all kinds of "sparing" policies for older shift workers. Little is known about the problems and needs of shift workers in these additional working years (44), demanding further research to sustainable employability of shift workers.
- A possible strategy to facilitate sustainable employability of shift workers, is to implement new shift systems. Our results support ergonomic shift scheduling recommendations, yet cut-off values (e.g. the optimum number of consecutive working days) and a prioritization in importance remain debatable. More research is needed to compare the pros and cons of different shift systems and schedules to provide more insight into the most demanding shift schedule characteristics and to come up with new innovative designs.
- New innovative designs may originate in intervening on personal characteristics, i.e. to design personalized shift systems. Individualization of shift work schedules offers the opportunity to align with chronotype, something workers intuitively do when offered the opportunity (53). A pilot of a chronotype-based schedule showed promising results

regarding sleep quality and duration, wellbeing and leisure activities (54). Further research is needed to come up with other personal characteristics next to age and chronotype (e.g. life phase or metabolic type) and to examine the long-term effects of such personalized shift systems on health, performance and social wellbeing.

- Next to the research needs regarding older shift workers, are the research needs for on-call workers. Distal on-call work is a scarcely studied but demanding working time arrangement. The use of on-call work might increase in the future due to technological developments making full shift coverage not needed anymore. More research is needed to provide insight in the effects of on-call work over time.

Pragmatic issues of work-placed intervention research

- There is still a lack of well-controlled studies examining the effects of shift system interventions (38, 40). A randomized control trial (RCT), the strongest research design, is often not possible due to organizational and logistic constraints. Alternative designs are available and feasible (e.g. stepped wedge, propensity scores, instrumental variables, multiple baseline design, interrupted time series, difference-in-difference and regression discontinuity) (55), allowing a more pragmatic approach, like the one used in this thesis, to meet the need for more applied shift work research.
- Applying a more pragmatic approach challenges research to align with shorter project cycles of (private) organizations compared to the usually long project-cycles in research, e.g. by having questionnaires, promotional material and an evaluation protocol available and ready to use or to use already available register data.
- Although not touched upon in this thesis, new measurement methods like wearables and data from other sources, e.g. cell phone usage, can help in gathering additional data without interrupting business processes. This kind of new technology offers opportunities for larger sample sizes and on the job assessments. However, some important ethical and privacy issues need to be resolved.

Towards an integral approach for shift work research

- There is a need for a more integral framework, like the one proposed by Merkus et al. (56), to disentangle working times, physical and psychosocial factors, and person-related factors. Examining the interrelations and interactions between the three domains may provide insight how actions on one domain affect the other domains and can help to develop guidelines when to intervene on which domain.
- Another important factor to include in an integral approach is time, as sustainable employability is continuous evolving through the working life. A life-course approach (57) including precise and repeated assessments of working time arrangements and health-, work- and social-related factors over time will open opportunities to better examine cause and effect and relative contributions of different domains.

Implications and challenges for practice

Six studies were conducted to examine effects of shift work and the possibilities of implementing new shift systems to enhance sustainable employability among different organizations, shift systems and persons. Several lessons for practice can be learned from our results and experiences. In this section, the implications and challenges for practice are discussed in general, as the composition of our study population does not allow us to formulate recommendations for shift workers of 55 years and older. General implications and challenges are discussed on the three levels of action to ensure sustainable employability of shift workers that were distinguished previously (58), namely the work organization, the worker and the organization. The level of the work organization refers to how work is organized, e.g. the working conditions including the shift system. On the level of the workers, implications and challenges are formulated for the individual workers, e.g. in terms of actions that individual workers can take. The organizational level covers HR-related policies and regulations, including implications and challenges for the occupational physician.

The work organization

- When non-ergonomic shift schedules are in place, implementing a new shift system may enhance sustainable employability of shift workers. We recommend to use ergonomic shift scheduling criteria and accommodate shift workers' personal preferences as much as possible.
- Implementing a new shift system has a large impact on the organization and its workers. A careful implementation process may therefore increase the likelihood of successful implementation. For a successful implementation, we advocate based on our research and in line with other shift work experts the use of worker participation, continuous information and communication, use of champions of change, proper project management and an effect evaluation (59).
- Additional measures to ensure sustainable employability of older shift workers according to Härmä are prevention of health problems (e.g. reducing excessive work hours and night shifts) and decrease of work load (e.g. decrease of work hours) (44). A critical assessment of the production process may provide opportunities to reorganize work processes, diminishing excessive work hours and night shifts. Work hours may be decreased by facilitating part-time employment, e.g. via company, sector or national regulation.

The workers

- Sustainable employability is a joint responsibility of employee and employer. This implies that workers need to play an active role in sustaining their personal employability. From this notion we advocate the following for workers (getting) involved in shift work:

- Our experience is that shift systems changes are a delicate topic for shift workers due to the possible impact on work, social life and financial compensation. Still, it is crucial to develop more knowledge on the effects that shift systems may have on the workers, to be able to address the workers' interests and perspectives. Workers should engage in shift system pilots or experiments with an open mind and without prejudices.
- In case of the introduction or a change of a new shift system, workers are encouraged to increase their knowledge of shift work and its potential impact, by actively participating in the design and implementation process, provided that the employer facilitates such participation. This would imply that shift workers organize themselves and provide input and feedback on the new shift system and its implementation. These recommendations are based on the findings (also in this thesis) that a participatory approach increases the likelihood of implementation and positive effects on health and work-related factors.
- Sustainable employability depends on common worker interests, but also on personal characteristics. An important personal characteristic is chronotype. Shift workers should be aware of the impact of their chronotype on sleep and act accordingly. For instance, adjusting sleep and dietary patterns or make properly use of any freedom of choice that a shift system may offer.

The organization

- If HR wants a shift system change to enhance sustainable employability, production departments should be involved in an early stage of the design and implementation process. Next to sustainable employability, gains should also be expressed in production terms, while keeping disruptions of the business process to a minimum.
- We experienced that fear of losing financial benefits is an important barrier for implementing new shift systems. New shift systems fitting within the current employment terms are more likely to be implemented.
- If employment terms probably need to be altered, a pilot study should first be performed in combination with a rigorous and objective effect evaluation, leaving the employment terms unchanged, to provide shift workers a better judgement of the pros and cons of a new shift system.
- The occupational physician oversees all three levels of action (work organization, worker and enterprise) and holds thereby an ideal position to facilitate sustainable employability. The results of this thesis might help the occupational physician to formulate a balanced advise taking into account the effects of shift work, working circumstances and individual differences.

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Summary

Summary

This thesis is the result of the 'Shift Your Work' study, which aims to contribute to a better understanding of sustainable employability of older shift workers by implementing new shift systems. This thesis builds on two premises. The first premise constitutes that shift work becomes more demanding with older age (Part I), the second premise entails that the type of shift system may contribute to sustainable employability (Part II).

Part I: The ageing shift worker

The premise that shift work becomes more demanding with older age is based upon the adverse effects of shift work on health, performance and social life due to the disturbance of biological and social circadian rhythms in combination with the physiological deterioration with older age. Yet, at the intersection of shift work and age, evidence is lacking, leading to the overall objective of Part I: to examine the effects of shift work on health, work functioning and social life within different shift systems, with a special focus on age.

Chapter 1 provides a general introduction on the background on shift work, with definition, prevalence and trends in the Netherlands. Mechanisms of shift work that might lead to ill health, impaired performance and disturbed social life are discussed, followed by the rationales for Part I and II.

Chapter 2 investigated shift work exit in a prospective cohort study among 5640 shift and day workers of a large Dutch steel manufacturer. Health check data were gathered to identify individual and work-related characteristics at baseline. Workers were followed up for a period of five years using company registers to determine whether they 1) had left the organization, 2) had been absent for ≥6 months or 3) had been temporarily placed in less strenuous work. Individual and work-related predictors of shift work exit did not seem to differ in strength and magnitude neither between older and younger shift workers, nor between shift and day workers.

Chapter 3 examined the relation between chronotype, age, sleep and need for recovery. Previous research has shown that with older age, sleep duration shortens, sleep quality worsens and need for recovery increases. Furthermore, with older age, workers become more morning oriented, i.e. an earlier chronotype. Earlier chronotypes are known to have more difficulties sleeping after night shifts, while later chronotype have more difficulties sleeping before morning shifts. In a cross-sectional study among 261 shift workers, we investigated what matters most when it comes to sleep quality, sleep duration and need for recovery in shift workers: chronotype or age? We found no associations for age, yet, later chronotypes reported a shorter sleep duration and more awakening complaints before morning shifts. These results suggest that chronotype, rather than age, explains individual differences in sleep.

Chapter 4 addressed a completely other, yet burdening, shift system than reported in the previous two chapters, namely distal on-call work. Distal on-call work refers to a working

time arrangement in which workers are away from the workplace, but can be called back in case of an emergency. According to Dutch working time legislation, distal on-call work is considered resting time. In this cross-sectional study among 169 technical on-call workers, need for recovery was higher when on-call while not called, compared to not on-call, and even higher when called back to the workplace during an on-call period. On-call workers with poor mental health or high work family interference reported higher need for recovery, independently of being on-call or not. Workers with high work demands reported higher need for recovery, only when being on-call. We found no differences for older compared to younger workers.

Part II: Enhancing sustainable employability by implementing new shift systems

The shift system design is one of the key modifiable determinants to affect the potentially negative effects of shift work and has therefore been examined extensively. Still, challenges remain in determining the relative and combined contributions of shift system characteristics and how to effectively implement a new shift system to facilitate sustainable employability. The aim of Part II is therefore to examine the relation between the design of a shift system and measures related to sustainable employability and to explore the implementation process of a new shift system.

In **Chapter 5**, the shift system design was explored in a cross-sectional study among 491 shift workers. Eighteen shift schedules were classified according eight, shift schedule characteristics, based on ergonomic recommendations and expert opinions. These characteristics were: 1) number of consecutive shifts, 2) start time of the morning shift, 3) number of consecutive working days, 4) direction of rotation (i.e. forwards (M)orning to (E)vening to (N)ight or backwards NEM), 5) number of annual weekends off (i.e. Saturday and Sunday), 6) number of recovery days, 7) number of rest days before a night shift and 8) average weekly working hours. We examined associations between the shift schedule characteristics with shift-specific sleep complaints and need for recovery, and generic health and performance measures. Relatively few associations were found, of which the majority was in favor of the ergonomic recommendations. The healthy worker effect, limited variation between included schedules and the cross-sectional design might explain the paucity of significant results. **Chapter 6** explored the implementation process of a new shift system. In a qualitative study, we investigated the facilitating and impeding factors for the implementation of a new shift system. Interviews were conducted among production managers, trade unions and workers of six companies, of which three companies successfully implemented a new shift system and three companies cancelled the implementation. A facilitating factor was if the change in shift system served production goals. An impeding factor was alteration of current employment terms related to the shift system change, and thereby involvement of headquarters and trade unions. Employee participation, management vision and support were no guarantee

for successful implementation.
The final study, described in **Chapter 7**, investigated the effect of the workers' attitude towards change before implementation on changes in health, work ability, work functioning and work-family interference after implementation. The new shift systems were designed to adhere to ergonomic shift scheduling recommendations. Using a pre-post-measurement design, complete data were retrieved from 59 shift workers of nine companies planning a new shift system. Workers were asked about their attitude towards the new shift system before implementation. Furthermore, self-rated mental and physical health, work functioning, work ability and work-family interference were assessed before and 6-8 months after implementation. The results of this study indicate that a more positive attitude towards the new shift system before implementation is associated with increased self-rated mental health, increased work ability and decreased work-family interference after implementation. The intervention context, i.e. the change process in the organization, is probably an important factor in explaining workers attitude towards change, considering differences in workers' attitude could not be explained by age, health status, work functioning, work ability or work-family interference.

Finally, in **Chapter 8** a discussion of the main findings of this thesis is provided, alongside with methodological considerations and implications for research and practice.
In general, no evidence was found either supporting or opposing the two premises. In Part I, hardly any age-related differences were found for measures related to sustainable employability of shift workers. In Part II, ergonomic recommendations for the design of a shift system supported sustainable employability, although the evidence was weak, and new shift systems deemed hard to implement. Several explanations for these results may apply. First, other characteristics than age (e.g. chronotype) may better explain individual differences in outcomes related to sustainable employability of shift workers. Second, a healthy worker effect may have been present, i.e. only those workers best suited and adapted to shift work manage working at irregular times. Third, most participating companies had already ergonomic shift schedules in place, providing fewer options for further optimization of shift schedules. Few age-related effects, a relatively healthy study populations and already well-designed schedules might have led to a low sense of urgency to implement new shift systems.
In conclusion, the findings of this thesis have implications for research and practice. Considering the age distribution of the study sample, many shift workers are at the verge of working past the initial retirement age. The retirement age has recently been increased, while at the same time "sparing-policies" for older shift workers have been abandoned. Little is known about the problems and needs of shift workers in these additional working years, warranting further research to enhance sustainable employability of shift workers. A possible strategy is to design and evaluate new shift systems intervening on personal

characteristics, e.g. chronotype. Alternative research designs, next to a RCT, are needed to overcome logistical and time-based constraints. For practice, implementing new shift systems may help to enhance sustainable employability of shift workers, in particular when non-ergonomic shift schedules are in use. Ergonomic recommendations should be applied and shift workers' individual preferences accommodated as much as possible. The process towards implementation is as important as the design of a new shift system, implying a careful process before implementation, preferably using a participatory approach.

Samenvatting

Samenvatting

In dit proefschrift worden de resultaten van de ‘Shift Your Work’ studie beschreven. Deze studie heeft als doel een bijdrage te leveren aan kennis over duurzame inzetbaarheid van oudere ploegendienstwerknemers. In deze studie worden twee hypotheses onderzocht. De eerste hypothese is dat ploegendienst zwaarder wordt met toenemende leeftijd (Deel I). De tweede hypothese is dat het ontwerp van een ploegendienstrooster kan bijdragen aan duurzame inzetbaarheid (Deel II).

Deel I: De ouder wordende ploegendienstwerknemer

De aanname dat ploegendienst zwaarder wordt met toenemende leeftijd is gebaseerd op de nadelige effecten van ploegendienst op gezondheid, productiviteit en het sociale leven door de verstoring van biologische en sociale ritmes. Oudere werknemers zouden hiervan minder goed kunnen herstellen vanwege afnemende gezondheidsreserves. Voor deze aanname is echter nog weinig wetenschappelijk bewijs. De doelstelling van Deel I is daarom het onderzoeken van de effecten van ploegendienst op gezondheid, productiviteit en werk-privé balans in diverse ploegendienstroosters, waarbij er specifiek gekeken is naar verschillende leeftijdsgroepen.

Hoofdstuk 1 geeft een algemene inleiding over de achtergrond van ploegendiensten, met definities, prevalenties en trends in Nederland. Daarna volgt een beschrijving van mogelijke mechanismes waardoor het werken in ploegendienst kan leiden tot een slechtere gezondheid, lagere productiviteit en verstoorde werk-privé balans, afgesloten met de afzonderlijke aanleidingen en doelstellingen voor Deel I en Deel II .

In **Hoofdstuk 2** wordt uitval uit werk (uitstroom, langdurig verzuim en tijdelijk ander werk) onderzocht in een cohort studie bestaande uit 5640 ploegendienst- en dagdienstwerknemers van een grote Nederlandse staalfabrikant. Individuele (gezondheidsstatus en leefstijl) en werkkenmerken (psychosociale en fysieke taakeisen), afkomstig uit periodiek medische onderzoeken, zijn als nulmeting gebruikt. De deelnemers zijn vervolgens gedurende vijf jaar gevolgd aan de hand van bedrijfsregistratiegegevens, met de vragen of ze 1) de organisatie hadden verlaten, 2) meer dan 6 maanden hadden verzuimd, of 3) tijdelijk in minder zwaar werk waren geplaatst. De individuele en werkkenmerken bleken in relatie tot de uitkomsten nauwelijks te verschillen in grootte of richting, noch tussen oudere en jongere ploegendienstwerknemers, noch tussen ploegendienst- en dagdienstwerknemers.

Hoofdstuk 3 gaat in op de relatie tussen chronotype en leeftijd met slaap en herstelbehoefte. Eerder onderzoek heeft aangetoond dat oudere werknemers korter slaper, slechter slapen en een hogere herstelbehoefte hebben. Daarnaast worden werknemers met toenemende leeftijd meer een ochtendpersoon; een zogenoemde vroeger chronotype. Vroege chronotypes hebben vaak meer slaapproblemen na nachtdiensten, terwijl late chronotypes juist meer slaapproblemen ervaren voor ochtenddiensten. In een cross-sectionele studie onder 265 ploegendienstwerknemers stellen we de vraag wat het meeste verschil uitmaakt wat betreft slaapduur, slaapkwaliteit en herstelbehoefte: leeftijd of chronotype? We hebben geen verbanden gevonden voor leeftijd, maar we vonden wel dat late chronotypes voor ochtenddiensten korter slapen en meer problemen met wakker worden ervaren. Deze resultaten suggereren dat individuele verschillen in slaap vooral lijken samen te hangen met chronotype en niet zozeer met leeftijd.

In **Hoofdstuk 4** wordt de herstelbehoefte tijdens een periode van consignatiediensten onderzocht. Consignatiediensten zijn diensten tijdens de avonden en weekenden waarin werknemers beschikbaar moeten zijn om in geval van onvoorziene calamiteiten zo snel mogelijk terug te kunnen keren naar de werkplek. Consignatiediensten zijn volgens de Nederlandse arbeidstijdenwet rusttijd. In deze cross-sectionele studie onder 169 werknemers met consignatiediensten, bleek de herstelbehoefte tijdens een periode van consignatiediensten hoger ten opzichte van de reguliere werktijden. De herstelbehoefte was ook hoger dan tijdens reguliere werktijden als men niet was gebeld tijdens de consignatiedienst. Werknemers met een slechte mentale gezondheid en een verstoorde werk-privé balans rapporteerden een hoge herstelbehoefte, onafhankelijk of ze consignatiedienst hadden of niet. Werknemers met een hoge werkdruk rapporteerden alleen een hoge herstelbehoefte als ze een consignatiedienst hadden. Ook in deze studie hebben we geen verschillen gevonden tussen oudere en jongere werknemers.

Deel II: Verbeteren van de duurzame inzetbaarheid door middel van nieuwe ploegendienstroosters

Het ploegendienstrooster is één van de sleutelvariabelen om de nadelige effecten van ploegendiensten zoveel mogelijk te beperken. Ondanks dat er al veel onderzoek is gedaan naar het optimale rooster, is nog niet duidelijk welke roosterkenmerken, en in welke configuratie, de nadelige effecten het beste kunnen minimaliseren. Daarnaast is er nog weinig structureel onderzoek gedaan naar het implementatieproces van een nieuw ploegendienstrooster. Ook het verband tussen de attitude van werknemers ten opzichte van een nieuw rooster en hoe zij deze ervaren is nog niet direct onderzocht. De doelstelling van Deel II is dan ook het onderzoeken van de verbanden tussen het ontwerp van een ploegendienstrooster met gezondheids- en werkuitkomsten en het in kaart brengen van het implementatieproces van een nieuw ploegendienstrooster.

Hoofdstuk 5 gaat over het ontwerp van een ploegendienstrooster. Achttien roosters zijn beoordeeld op acht roosterkenmerken. Deze roosterkenmerken zijn gebaseerd op ergonomische roostercriteria en expertoordelen, te weten: 1) aantal opeenvolgende diensten, 2) starttijd van de ochtenddienst, 3) aantal opeenvolgende werkdagen, 4) rotatierichting (voorwaarts, d.w.z. O(chtend), M(iddag), N(acht) of achterwaarts NMO), 5) aantal weekenden vrij (d.w.z. zaterdag en zondag), 6) aantal hersteldagen, 7) aantal rustdagen voor een nachtdienst en 8) gemiddelde werkweek in uren. Vervolgens is onderzocht welke roosterkenmerken een verband hebben met slaapkwaliteit en herstelbehoefte apart voor de ochtend-, middag- en nachtdienst en meer generieke maten zoals vermoeidheid, ervaren gezondheid en werkfunctioneren. We hebben relatief weinig verbanden gevonden voor de roosterkenmerken noch met dienstspecifieke slaapkwaliteit en herstelbehoefte, noch met vermoeidheid, ervaren gezondheid en werkfunctioneren. Het merendeel van de weinige verbanden ondersteunden de ergonomische roostercriteria waarop de roosterkenmerken waren gebaseerd. Selectie-effecten, kleine verschillen tussen de roosterontwerpen en het cross-sectionele design van de studie zijn mogelijke verklaringen voor het geringe aantal gevonden verbanden.

In **Hoofdstuk 6** wordt ingegaan op het implementatieproces van een nieuw ploegendienstrooster bij zes bedrijven. In een kwalitatieve studie onderzoeken we de bevorderende en belemmerende factoren bij het implementeren van een nieuw rooster. Hiervoor zijn in dit onderzoek interviews gehouden met productiemanagers, vakbonden en werknemers van deze bedrijven. Bij drie van deze bedrijven is een rooster geïmplementeerd en bij drie andere bedrijven is het proces voor de daadwerkelijke implementatie afgebroken. Een bevorderende factor voor implementatie was wanneer een nieuw rooster bijdraagt aan het behalen van productiedoelstellingen. Een belemmerende factor was wanneer er een verandering van de arbeidsvoorwaarden nodig was. Verder bleek een participatieve aanpak geen garantie voor succes te zijn.

In **Hoofdstuk 7** wordt het verband onderzocht tussen de attitude van 59 werknemers ten opzichte van een roosterwijziging vóór implementatie op veranderingen in ervaren gezondheid, werkvermogen, werkfunctioneren en werk-privé conflict 6-8 maanden ná implementatie. Uit de resultaten bleek dat een meer positieve attitude ten opzichte van de roosterwijziging vóór implementatie gerelateerd is aan een betere ervaren mentale gezondheid, toegenomen werkvermogen en verminderd werk-privé conflict ná implementatie. De reden voor het nieuwe rooster en het proces vóór implementatie speelt kennelijk een belangrijke rol in de vorming van de attitude ten opzichte van de roosterwijziging. Verschillen in attitude konden namelijk niet verklaard worden door verschillen in leeftijd, ervaren gezondheid, werkvermogen, werkfunctioneren en werk-privé conflict.

In **Hoofdstuk 8** volgt een discussie van de belangrijkste bevindingen van de verschillende deelstudies, samen met methodologische overwegingen en implicaties voor de wetenschap en de praktijk.

In dit proefschrift is geen overtuigend bewijs gevonden voor het bevestigen dan wel weerleggen van de eerder beschreven hypotheses. In Deel I hebben we nauwelijks verschillen gevonden tussen verschillende leeftijdsgroepen in gezondheid, productiviteit en werk-privé balans. In Deel II blijken ergonomische roostercriteria slaapkwaliteit, herstelbehoefte, vermoeidheid, ervaren gezondheid en werkfunctioneren te ondersteunen, hoewel het bewijs zwak is en nieuwe roosters lastig te implementeren zijn. Verscheidene verklaringen kunnen aan deze bevindingen ten grondslag liggen. Ten eerste kunnen andere persoonlijke kenmerken dan leeftijd (bijvoorbeeld chronotype) een grotere rol spelen in het verklaren van individuele verschillen in duurzame inzetbaarheid. Ten tweede liggen selectie-effecten voor de hand, dat wil zeggen dat alleen die werknemers in ploegendienst blijven werken die daar het beste tegen kunnen en zich kunnen aanpassen. Ten derde hadden de meeste deelnemende bedrijven ploegendienstroosters die al grotendeels voldeden aan ergonomische roostercriteria, waardoor de mogelijkheid voor optimalisatie klein was. De kleine verschillen tussen leeftijdsgroepen, een relatief gezonde populatie en roosters die al goed voldeden zouden redenen kunnen zijn tot weinig noodzaak om te veranderen.

De bevindingen in dit proefschrift kunnen vertaald worden naar concrete implicaties voor wetenschap en praktijk. Voor de wetenschap ligt er nog een grote uitdaging om de problemen, behoeften en uitdagingen van oudere werknemers in de ploegendienst te onderzoeken. In de komende jaren zal namelijk een steeds groter aandeel van ploegendienstwerknemers langer door (moeten) werken. Niet alleen vanwege een verhoging van de pensioengerechtigde leeftijd, maar ook omdat allerlei ontziemaatregelen onder druk staan. In algemene zin blijkt het vooral in zware beroepen (inclusief ploegendienst) niet eenvoudig om door te werken tot de pensioengerechtigde leeftijd. De opgedane kennis dient vervolgens vertaald te worden in nieuwe interventies en beleid en deze in de praktijk te testen. Een mogelijke ontwikkelstrategie hiervoor is het personaliseren van ploegendienstroosters, bijvoorbeeld naar chronotype. Alternatieve onderzoeksmethoden anders dan een RCT zijn daarbij nodig om zoveel mogelijk tegemoet te komen aan logistieke en tijdsgebonden eisen van de praktijk.

Voor de praktijk betekent bovenstaande het volgende. Wanneer een rooster niet voldoet aan ergonomische roostercriteria, kan de invoering van een nieuw rooster dat wel voldoet aan ergonomische roostercriteria bijdragen aan de inzetbaarheid van ploegendienstwerknemers. Zijn er echter al ergonomische roosters in gebruik, is er weinig gezondheidswinst te verwachten van het verder fijn slijpen van een rooster. In dat geval is er waarschijnlijk meer winst te behalen door het personaliseren en individualiseren van roosters. In alle gevallen dient men in het achterhoofd te houden dat het proces voorafgaand aan de implementatie van een nieuw ploegendienstrooster minstens zo belangrijk is als het ontwerp zelf. Het implementeren van een nieuw rooster vraagt om een zorgvuldig proces vooraf, bij voorkeur in samenwerking met werknemers en werkgever voor het vergroten van het draagvlak.

Dankwoord

Dankwoord

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Curriculum vitae

Curriculum vitae

Hardy van de Ven is geboren op 29 juli 1984 te Nijmegen. Na zijn atheneum diploma begint Hardy in 2002 aan de studie Technische Bedrijfskunde aan de Rijksuniversiteit Groningen. In 2009 studeert hij af met een Master thesis onderzoek naar strategische capaciteitsplanning van de centrale sterilisatie afdeling van het Universitair Medisch Centrum Groningen. Na een jaar reizen begint Hardy in 2010 aan het onderliggende promotieonderzoek, betreffende de duurzame inzetbaarheid van oudere ploegendienstmedewerkers en het ontwerp en invoeren van nieuwe ploegendienstroosters. Sinds 2015 werkt hij als onderzoeker en adviseur bij TNO, afdeling Sustainable Productivity and Employability. In zijn huidige werk gebruikt hij actief de opgedane kennis uit zijn promotieonderzoek, maar onderzoekt hij ook nieuwe manieren om de duurzame inzetbaarheid van ploegendienstwerknemers te verbeteren. Naast werktijden, onderzoekt Hardy ook de duurzame inzetbaarheid van andere kwetsbare groepen, zoals bijvoorbeeld flexwerkers en werknemers met een afstand tot de arbeidsmarkt.

Hardy woont samen met Hanneke en hun dochterje Else in Leiden. In zijn vrije tijd trekt Hardy graag de wereld over, speelt hij tennis en geniet hij van het goede leven.

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