Sleep and sleepiness among shift workers in the air ambulance service

Tine Almenning Flaa

Thesis for the degree of Philosophiae Doctor (PhD)
University of Bergen, Norway
2023

UNIVERSITY OF BERGEN

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Date of defense: 19.01.2023

Year: 2023

Title: Sleep and sleepiness among shift workers in the air ambulance service

Name: Tine Almenning Flaa

Print: Skipnes Kommunikasjon / University of Bergen

Scientific environment

This doctoral thesis was completed over a four-year PhD-period from 2018 to 2022 (including maternity leave) at the Department of Global Public Health and Primary Care (IGS), Faculty of Medicine, University of Bergen. The project was financed by The Norwegian Air Ambulance Foundation. During my PhD-period I was enrolled at the Norwegian Research School in General Practice, as well as the local research schools at the IGS and the Norwegian Air Ambulance Foundation. I was a member of the Bergen Sleep and Chronobiology Network, University of Bergen and affiliated with the Norwegian Competence Center for Sleep Disorders, Haukeland University Hospital. The data collection was conducted in collaboration with the Norwegian Air Ambulance.

My main supervisor, Post-doctor Siri Waage, is affiliated with the Department of Psychosocial Science, Faculty of Psychology, University of Bergen (Department of Global Public Health and Primary Care, Faculty of Medicine, University of Bergen from 2018-2020). I have been fortunate to have several co-supervisors. My co-supervisors, Professor Bjørn Bjorvatn and Professor Erik Zakariassen, are both affiliated with the Department of Global Public Health and Primary Care, Faculty of Medicine, University of Bergen. Further, my co-supervisors Professor Ståle Pallesen and Professor Anette Harris, are both affiliated with the Department of Psychosocial Science, Faculty of Psychology, University of Bergen. Siri Waage, Bjørn Bjorvatn, and Ståle Pallesen are also affiliated with the Norwegian Competence Center for Sleep Disorders, Haukeland University Hospital.

Acknowledgements

First, I would like to extend my gratitude to the Norwegian Air Ambulance Foundation for investing in this project and making it possible for me embark on this endeavour. I am also thankful for the research environments at the Norwegian Air Ambulance Foundation and IGS for taking me in and integrating me in the milieus. It has resulted in great colleagueship and friendships.

I could not have undertaken this journey if it was not for the groundwork laid down by the distinguished team of supervisors. I am grateful for having such a knowledgeable and professional, but also kind and welcoming, group of supervisors to guide me through this project.

I would like to express my deepest gratitude to my main supervisor, **Siri Waage**. Throughout the project, you have integrated me in the milieu, both socially and scientifically. Thank you for your patience and guidance, and for efficiently calming me down from my, at times, irrational worries. You have been generous with time and availability, and I am proud to be your first candidate!

Thank you, co-supervisor **Erik Zakariassen**, for providing insight into prehospital medicine and for stopping by my desk both in Kalfarveien and at Alrek. I appreciate your historical fun facts and talks during lunch and was truly grateful for your moral support preceding my first oral presentation at AirMed five months into my PhD.

A special thanks to my co-supervisors, **Bjørn Bjorvatn** and **Anette Harris**, for sharing your expertise and for providing thorough feedback whenever needed. You have also been great travel companions on conferences around the world. Last, but not least co-supervisor **Ståle Pallesen**. Thank you, not only for your invaluable input throughout my PhD, but also for supervising me in both my bachelor's- and master's-degree. You were the one who introduced me to research and played a pivotal part in me taking on a PhD. For this I am very grateful.

I wish to extend my appreciations to the additional co-authors for knowledgeable input on the papers in the thesis: **Hilde Gundersen**, **Jo Røislien**, and **Pia Gatterbauer-Trischler**.

Another special thanks to my leader at the Norwegian Air Ambulance Foundation, **Ingunn Riddervold**, for always being supportive, checking in on me, and making sure I had an optimal working environment during the project.

This project would not have been possible if it was not for the pilots and HCMs, especially at the NLA, but also at the CFV. Thank you all for your contribution and effort. A special thanks to **Hans Ivar Kubberød** and the Fatigue Safety Action Group at the NLA for letting me be a fly on the wall during your FRMS work and providing me with first-hand knowledge from the HEMS perspective.

To **Sahar**, my dearest friend at the office, thank you for all digressions, laughter, and gastronomic inspiration. Our breaks sometimes felt lifesaving.

I am grateful for all my family and friends who have patiently heard me out about the ups and downs, and for enduring my endless pointing at flying NLA helicopters. Especially my best friend **Maja,** for your exquisite humour and banter which has helped we ease off after stressful days.

My sweetest **Levi**, who came along towards the end of my PhD journey. He has taught me that life is much more than just work, that toddlers are some of the best comedians, and that none are spared from the sentimental clichés. He has also given me first-hand experience with long-term sleep deprivation, for which I am not particularly grateful.

“*People who say they sleep like a baby usually don’t have one.”*

Leo J. Burke

To **Thomas** – my second-best friend and the love of my life – thank for you for being my solid rock in times of frustration and insecurity, and my biggest cheerleader in times of success and progress. You have handled this journey with grace even when I at times have been a PhD-monster. Your patience and loving support have been indispensable.

Abstract

The 24-h society provides us with unlimited access to multiple services which has resulted in an increased demand for shift work and long work hours. These arrangements imply activity that coincides with habitual sleep hours, consequently leading to a degradation of sleep in our priorities. Subsequently, a link has been established between shift work and negative outcomes regarding health, performance, and safety. The workers in the Helicopter Emergency Medical Service (HEMS) represent an occupational group who work both shift and long hours. In the Norwegian Air Ambulance (NAA), the pilots and HEMS crew members (HCMs) work seven consecutive days and are during these days operative at all hours.

This thesis aimed to examine how the shift schedule affected the pilots and HCMs working for the NAA regarding sleep and sleepiness. In order to gain further knowledge from outer perspectives, the third paper also included an Austrian HEMS operator, Christophorus Flugrettungsverein (CFV), who had a similar work schedule. To investigate this, sleep and sleepiness was registered in two three-week data collections in the NAA. Wave 1 during the fall/winter of 2014 and Wave 2 during the spring/summer of 2015. A corresponding three-week data collection was conducted in the CFV during the spring/summer of 2016.

In Paper 1, we examined sleepiness among shift working pilots and HCMs in the NAA. Sleepiness was assessed over the three consecutive weeks: the week before work, the workweek, and the week after work. The pilots and HCMs completed wake diaries containing Accumulated Time with Sleepiness (ATS) scale and Karolinska Sleepiness Scale (KSS) during all three weeks. Additionally, reaction time tests were completed during the workweek. The results revealed low sleepiness scores during all three weeks. Measured by the ATS, the lowest sleepiness levels were found during the workweek (compared to the week before and after work). The KSS revealed low sleepiness levels over the course of a workweek, with slightly elevated levels on the first workday. Over the course of a workday, the KSS scores indicated normal fluctuation in sleepiness, drifting in a slight U-curve from 08:00 to 00:00 h with the

highest sleepiness levels reported at midnight. The reaction time tests revealed no change throughout the workweek.

In Paper 2, the aim was to assess sleep among pilots and HCMs working for the NAA. Sleep diary and actigraphy were used to examine sleep during the workweek in two seasons: a season with fewer missions (Wave 1) and a season with more missions (Wave 2). Additionally, sleep was examined over three consecutive weeks: the week before work, the workweek, and the week after work, in both waves. A comparison between the workweeks suggested that the workers went to bed later and spent less time in bed during Wave 2 compared to Wave 1. The results over three consecutive weeks indicated that the workers delayed their bedtime and wake-up time, spent more time in bed, spent more time awake after sleep onset, and had lower sleep efficiency (measured by actigraphy) compared to the week before and after work. Still, subjectively reported total sleep time was over 7 h in both workweeks.

In Paper 3, the aim was to investigate the sleep and sleepiness during the workweek of HEMS pilots of two different HEMS operators who have a similar shift schedule. Pilots working for the Norwegian NAA and the Austrian CFV participated in the study. Sleep diary and actigraphy was applied to assess sleep, while the KSS was used to investigate levels of sleepiness during the workweek. The results for both pilot groups combined, suggested that the sleep period was delayed towards the end of the workweek. When we compared the two pilot groups, the NAA pilots had a more delayed sleep period, spent more awake after sleep onset, spent more time in bed, slept longer, and had lower sleep efficiency compared to the CFV pilots. For both pilot groups collapsed, the levels of sleepiness during the workweek were overall low although we found slightly increased scores on the first workday. The sleepiness levels over the course of a workday (08:00–00:00 h) were normal.

In conclusion, the three papers suggest that the pilots and HCMs obtain adequate amounts of sleep and experience low levels of sleepiness both during their weeks off and during their workweek. Possible sleep promoting factors during the workweek include protection from domestic and social obligations, base facilities, rest between shift bouts, and highly selected personnel. Thus, the current shift schedules of the included HEMS operators seem to be a good fit for this particular occupational group regarding sleep and sleepiness. Although, the sleep was to some extent more affected during the workweek compared to the weeks off work. Therefore, a focus on developing a state-of-the-art Fatigue Risk Management System is essential in order to protect the workers and their surroundings against the known detriments that follow shift work. Further research on such occupational settings is also important to have updated information about the status in these settings.

Sammendrag

Det moderne 24-timers samfunnet gir oss ubegrenset tilgang på et bredt spekter av tjenester som har resultert i et økt behov for skiftarbeid og lang arbeidstid. En slik måte å organisere arbeid på, innebærer aktivitet på et tidspunkt hvor søvn og hvile er naturlig, som videre har ført til en nedprioritering av søvn. Dette kan få negative konsekvenser for skiftarbeideren, og resultat fra forskning har etablert en assosiasjon mellom skiftarbeid og negative utfall i både helse, prestasjon, og sikkerhet. De ansatte i luftambulansetjenesten representerer en gruppe arbeidere som jobber skift og har lang arbeidstid. I Norsk Luftambulanse (NLA) jobber pilot og redningsmann en skiftordning som er organisert i syv påfølgende 24-timers vakter, hvor de er operative døgnet rundt.

I denne avhandlingen undersøkte jeg hvordan søvn og søvnighet hos piloter og redningsmenn ansatt i NLA ble påvirket av skiftordningen. For å lære mer om dette fra andre perspektiv, inkluderte vi i tredje artikkel HEMS piloter ansatt i Østerrikske Christophorus Flugrettungsverein (CFV), som har en lignende syvdagers skiftordning. Data på søvn og søvnighet ble samlet inn i to 3-ukers perioder i NLA: høst/vinter i 2014 (Wave 1) og vår/sommer 2015 (Wave 2). En tilsvarende 3-ukers datainnsamling ble gjennomført i CFV i løpet av vår/sommer 2016.

I første artikkel ønsket vi å undersøke søvnighet blant skiftarbeidende piloter og redningsmenn i NLA. Søvnighet ble registrert over tre påfølgende uker: uken før vakt, vaktuken, og uken etter vakt. De ansatte fylte ut våkenhetsdagbøker bestående av Accumulated Time with Sleepiness (ATS) og Karolinska Sleepiness Scale (KSS) i alle tre ukene. De utførte i tillegg reaksjonstidtester i vaktuken. Resultatene viste lave nivå av søvnighet gjennom alle de tre ukene. Målt med ATS fant de laveste søvnighetsskårene under vaktuken sammenlignet med ukene før og etter vakt. Resultatene fra KSS indikerte lave søvnighetsskårer gjennom hele vaktuken, men med litt høyere skårer på første vaktdag sammenlignet med de resterende vaktdagene. I løpet av en vaktdag viste KSS-skårene normale søvnighetsnivå som fulgte en svak

U-kurve fra kl 08:00 til 00:00, hvor de høyeste skårene ble rapportert ved midnatt. Reaksjonstidtestene viste ingen endring i løpet av vaktuken.

I andre artikkel ønsket vi å undersøke søvn blant piloter og redningsmenn ansatt i NLA. Søvndagbok og aktigrafi ble benyttet for å registrere søvn gjennom vaktuken i to sesonger: en sesong med færre oppdrag (Wave 1) og en sesong med flere oppdrag (Wave 2). Søvn ble også registrert over tre påfølgende uker (uken før vakt, vaktuken, uken etter vakt) i begge sesonger. En sammenligning mellom vaktukene antydet at de ansatte la seg senere og tilbrakte mindre tid i sengen i Wave 2 sammenlignet med Wave 1. Over tre påfølgende uker viste resultatene at de ansatte forskjøv leggetid og stå-opp tid, tilbrakte mer tid i sengen, mer tid våken etter innsovning, og hadde lavere søvneffektivitet (målt med aktigrafi) i vaktuken sammenlignet med ukene før og etter vakt. Til tross for dette var likevel den subjektivt rapporterte søvnlengden over 7 timer i begge vaktukene.

I tredje artikkel undersøkte vi søvn og søvnighet i løpet av en vaktuke hos luftambulansepiloter i to forskjellige luftambulanseoperatører, som begge hadde lignende skiftordning. Piloter ansatt i Norske NLA og Østerrikske CFV deltok i studien. Søvndagbøker og aktigrafi ble benyttet for å registrere søvn, mens KSS ble brukt for å undersøke søvnighetsnivåene i løpet av vaktuken. Resultatene for pilotgruppene sammenslått antydet at søvnperioden ble forskjøvet mot slutten av vaktuken. En sammenligning av de to pilotgruppene avslørte at NLA pilotene hadde en mer forskjøvet søvnperiode, tilbrakte mer tid i sengen, mer tid våken etter innsovning, sov lenger, men hadde også lavere søvneffektivitet enn CFV pilotene. Søvnighetsskårene var totalt sett lave, med en svakt høyere skåre på første vaktdag sammenlignet med de resterende vaktdagene, for begge pilotgruppene sammenslått. I løpet av en vaktdag (kl 08:00-00:00) viste søvnighetsskårene normale bevegelser og lave søvnighetsnivåer.

Oppsummert viser resultatene fra de tre artiklene at pilotene og redningsmennene får tilstrekkelige mengder søvn og opplever lav grad av søvnighet både i friperiodene, men også i løpet av vaktuken. Mulige beskyttende faktorer for søvn i vaktuken er blant annet fri fra familiære og hjemlige forpliktelser, basefasiliteter, tilstrekkelig lang friperiode mellom vaktukene, og høye seleksjonskrav til de ansatte. Funnene kan tyde på at skiftordningen fungerer bra for denne spesifikke yrkesgruppen, med tanke på søvn og søvnighet. Til tross for dette så vi også at søvnen til en viss grad ble mer påvirket under vaktuken sammenlignet med ukene av vakt. Det er derfor viktig å sette søkelys på videreutvikling og kontinuerlig oppdatering av Fatigue Risk Management Systemer for å kunne beskytte de ansatte og deres omgivelser mot de velkjente negative konsekvensene som følger skiftarbeid. Videre forskning på slike yrkesgrupper er også viktig for å ha oppdatert informasjon om status i slike samfunnsviktige yrkessettinger.

List of Publications

1. Flaa, T., Harris, A., Bjorvatn, B., Gundersen, H., Zakariassen, E., Pallesen, S., & Waage, S. (2019). Sleepiness among personnel in the Norwegian Air Ambulance Service. *International Archives of Occupational and Environmental Health*, 92(8), 1121-1130. https://doi.org/10.1007/s00420-019-01449-w.

2. Flaa, T. A., Bjorvatn, B., Pallesen, S., Røislien, J., Zakariassen, E., Harris, A., & Waage, S. (2021). Subjective and objective sleep among air ambulance personnel. *Chronobiology International*, *38*(1),129-139. https://doi.org/10.1080/07420528.2020.1802288.

3. Flaa, T. A., Bjorvatn, B., Pallesen, S., Zakariassen, E., Harris, A., Gatterbauer-Trischler, P., & Waage, S. (2022). Sleep and Sleepiness Measured by Diaries and Actigraphy among Norwegian and Austrian Helicopter Emergency Medical Service (HEMS) Pilots. *International Journal of Environmental Research and Public Health*, 19(7), 4311. https://doi.org/10.3390/ijerph19074311.

The articles will be referred chronologically as Paper 1, Paper 2, and Paper 3.

List of Figures and Tables

List of Abbreviations

ANOVA = Analysis of Variance

ATS = Accumulated Time with Sleepiness scale

β = unstandardized beta coefficient

CFV = Christophorus Flugrettungsverein

EASA = European Union Aviation Safety Agency

EEG = electroencephalogram

EMG = electromyogram

EOG = electrooculogram

ESS = Epworth Sleepiness Scale

FRMS = Fatigue Risk Management System

HCM = HEMS crew member

HEMS = Helicopter Emergency Medical Service

KSS = Karolinska Sleepiness scale

LMM = Linear Mixed Models

M = mean

NAA = Norwegian Air Ambulance

NASA = National Aeronautics and Space Administration

NLA = Norsk Luftambulanse

NREM = non-rapid eye movement

N1 = sleep stage 1

N2 = sleep stage 2

N3 = sleep stage 3

Process C = circadian process

Process S = homeostatic process

PSG = polysomnography

PVT = Psychomotor Vigilance Task

REM = rapid eye movement

SCN = suprachiasmatic nuclei

Contents

1. Introduction

Humans are diurnal animals with an innate tendency to be active during the day and rest during the night. With the industrialization and the introduction of electric light, an increase in 24-h services has taken place. These services are being provided by humans, called shift workers, who are forced to rearrange their activity/rest pattern and alter their sleep period. This way of working and living misaligned with their innate/endogenous circadian rhythms are known to impair sleep and may further negatively affect health and performance. For this reason, studies on shift work are important in order to extend our knowledge about the effects of different shift compositions and schedules on sleep, as well as how these may play out across the spectra of inter-individual differences.

One of the aforementioned services is healthcare, including the Helicopter Emergency Medical Service (HEMS). This occupational group provides medical assistance around the clock, and thus work outside the normal 8-h day. The inherent nature of the work tasks places the workers in a high-risk occupation, potentially facing complex missions in challenging terrain, sometimes with scarce knowledge about what they are approaching [1]. There are limited studies directed specifically at the workers in the HEMS and their shift schedules. Therefore, this thesis examined sleep and sleepiness among pilots and Helicopter Emergency Medical Service crew members (HCMs) working for the Norwegian Air Ambulance (NAA). For the third paper, the Austrian HEMS operator Christophorus Flugrettungsverein (CFV) who have a similar shift schedule were studied together with the NAA.

1.1 Shift work

Shift work is essential in order to maintain a 24-h coverage of healthcare, production, and transport services critical to public safety. It can be defined as work that takes place between 19:00 and 06:00 h [2], thus involving work at irregular and unusual hours (i.e., night shifts) compared to the normal daytime work arrangement [3]. In 2015, 21% of all employees in the EU participated in shift work – a 17% increase in five years [4]. In Norway, 33% of the workforce worked outside ordinary hours in 2020 [5].

Shift work entails irregular and non-traditional sleep/wake schedules, usually misaligned with the diurnal rhythm. In an effort to protect the employees' health and safety as well as the safety of operations, working time has been regulated. The European Working Time Directive and The Working Environment Act in Norway represent legislative structures intended for such regulations. They determine the limits for workhours per week, day and night, as well as minimum periods of rest [6, 7]. However, the structure and organization of shift schedules vary widely as operational requirements of industries and occupations differ from each other. Thus, certain exceptions are negotiated between employers and unions for occupations that need to operate outside the normal daytime workhours.

There are numerous ways to organize shift work schedules, and these can differ according to several dimensions. An overview loosely based on the domains outlined by Steven and colleagues [8] is presented below.

i. Type of shifts: start and end time of shift (i.e., early morning, evening or night), on-call or present, on-site or off-site.
ii. Night work: shift work schedules with or without night work
iii. Combination of shifts: two shift system (morning and evening) or three shift system (morning, evening, and night)
iv. Length of shift: 8 h, 12 h, 24 h
v. Regularity: permanent or rotating shifts
vi. Direction of rotation: clockwise or counterclockwise
vii. Speed of rotation: daily or weekly changes in type of shift
viii. Rest periods: length and placement (i.e., ≤11 h between shifts are called quick returns)
ix. Duration: years of exposure to shift work
x. Intensity: amount of shift work per month and year

Night work entails work during hours that coincide with the workers' normal sleep period and may be regarded as one of the most demanding dimensions of shift work. It is also common in the health care sector, including the HEMS. No strict definition of night work exists but there are numerous suggested descriptions: work for 3 h or more between 00:00 and 06:00 h [9], shift start between 18:00 and 04:00 h [10], or work that takes place between 21:00 and 06:00 h [7]. Approximately 19% of the European work force report engaging in night work at least once a month [4], whereas 15% of the Norwegian work force work sometimes or regularly at night [5].

Two other dimensions of shift work that are common in the health care sector are long work hours and on-call shifts. Long work hours are defined as shifts exceeding 10 h, while on-call shifts include a scheduling approach that provides full coverage during off-peak hours when normal staff resources are absent. During on-call work, the employee may either be on-site or remain off-site, depending on occupation and arrangement [11]. Contrary to other shift work arrangements, on-call work generally allow for sleep opportunities between calls. The work setting of the pilots and HCMs in the NAA is comprised by night work, long work hours (24-h shifts over seven consecutive days) and on-call work, as they live on the base during the workweek and take on missions at all hours in an on-call, on-site manner.

1.2 Sleep and circadian rhythm

Extensive research has been conducted on a quest to increase our knowledge about sleep and its functions. Although the elemental functions remain largely undiscovered, we have gained insight into several aspects of sleep.

1.2.1 Sleep

A behavioural description of sleep characterizes it as a reversible, passive state of periodic rest which entails reduced motor activity and reactivity to external stimuli [12]. However, sleep is also defined based on physiological parameters that track patterns of electrical activity in the brain. All species seem to engage in some form of sleep or inactivity. From an evolutionary perspective, it could seem maladaptive as it is a vulnerable state that inhibits reproduction and food preservation. Still, it has been worth dedicating one-third of human lifespan to sleep [13]. It is paradoxical that the answer to the fundamental question “why?” remains unresolved. Over the years, theories have emerged in an effort to answer this question, including theories on synaptic plasticity and memory consolidation [14], emotional regulation [15], metabolic functions [16], and removal of neurotoxins [17]. The adaptive features have also been advocated, including reduced energy usage and timing behaviour aligned with the light/dark cycle [12]. Nevertheless, sleep has for decades been perceived merely as cessation of activity. Thus, along with the introduction of electric light in the late 1800s which expanded our days, this may explain our progressive detachment from sleep as a basic human need that follows a circadian rhythm.

1.2.2 Circadian rhythm

Closely related to sleep is the circadian rhythm (in Latin circa diem = about a day). Our circadian rhythms reflect endogenous oscillations with a period lasting approximately 24 h as defined by the earth’s rotation. These rhythms are governed by the suprachiasmatic nuclei (SCN), the circadian pacemaker located in the hypothalamus, but exists on a cellular-molecular basis throughout the brain and body [18]. Humans are diurnal, meaning we are inherently active during the day and inactive during the night. Various physiological functions follow this rest/activity pattern, such as the core body temperature which peaks in the evening and reaches its nadir during the early morning hours [19]. Although there are large individual differences, the period of the innate rhythm normally exceeds 24 h (24.18 h) [20]. For this reason, entrainment by external cues is essential in order to readjust our internal clock to the light/dark cycle. Such corrections are made by “zeitgebers” or time givers including light, temperature, food, and social factors.

The circadian rhythms regulate numerous behavioural, physiological, and biochemical functions, where the sleep/wake rhythm is the most prominent. For the sleep/wake cycle, light is the most important time giver. Via photoreceptors and neural pathways, the SCN is entrained by environmental cycles of light and dark which further regulate melatonin release in the pineal gland. Melatonin is a circadian hormone that increases in the evening, peaks around 02:00 to 04:00 h, and then descends to baseline in the late morning hours. However, the release of melatonin is inhibited by exposure to blue light [21, 22]. The role of melatonin in sleep is not fully elucidated, yet their temporal relationship is evident, and melatonin is known to enhance sleep propensity [23, 24]. Thus, the circadian rhythm is susceptible to alterations by exposure to light, i.e., relocation to different time zones or work during a window of circadian low. Such alterations lead to circadian misalignment and affect sleep negatively. However, there are interindividual differences concerning circadian rhythmicity, where chronotypes are one way to differentiate. Chronotypes refer to morning/eveningness, a tendency towards being an early "lark" or a late "owl", usually indicated by preferred sleep timing. A typical lark tends to wake up early in the morning and go to bed early in the evening, while the typical owl stays up until late in the evening/night and tends to wake up later in the morning/day. Some individuals also have a circadian profile that include a post-lunch dip in alertness and core body temperature [25].

1.2.3 Sleep architecture

Although a sleeping person appears unresponsive and inactive, the brain is still very much in an active state. Sleep at an electrophysiological level is defined by polysomnography (PSG) consisting of at least three basic measures: electroencephalogram (EEG), electromyogram (EMG), and electrooculogram (EOG). The EEG measures brain waves, the EMG measures limb movement, while the EOG measures eye movement. Based on the PSG, sleep is divided into two main sleep states: rapid eye movement (REM) sleep and non-rapid eye movement (NREM) sleep. Based on the manual published by the American Academy of Sleep Medicine in 2007, NREM is further subdivided into N1, N2, and N3, paralleling a sleep dept continuum [26]. N1 represents transition from wake to sleep, consisting of alpha and theta waves. N2 represents light sleep dominated by theta waves and includes characteristic waveforms such as sleep spindles that reduce reactivity to external stimuli and K-complexes, involved in memory consolidation. N3, also called deep sleep, primarily consists of slow wave activity (delta waves). During the REM stage, the brain reaches its highest activity level of the sleep period – on the EEG it resembles a wake brain (beta and alpha waves). It is characterized by dreams, muscle atonia, and periodically bursts of rapid eye movement. The majority of deep sleep (N3) is obtained in the first third of the sleep period, whereas REM sleep dominates the last third of the sleep period. A healthy adult enters the sleep through NREM with N1 and progresses to the deeper sleep stages N2 and N3, before reactivating the brain by REM sleep transition. Throughout the night, NREM and REM continues to alternate in 90-110 min cycles [27, 28]. Hypnograms are visual representations of sleep cycles throughout a night of sleep (Figure 1).

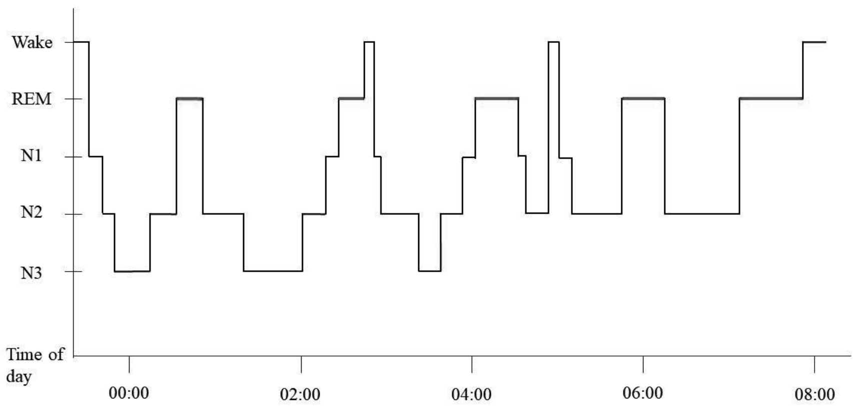

Figure 1. An illustration of a hypnogram showing normal distribution of different sleep stages throughout the night.

1.2.4 Sleep regulation

The two-process model of sleep conceptualizes sleep regulation based on the interplay of two processes: Process S and Process C (Figure 2) [29, 30]. Process S represents the homeostatic factor, a proxy for accumulated sleep pressure that increase during wakefulness and activity. Process C represents the circadian factor, the self-sustained and relatively constant oscillations that comprise our circadian rhythms. In humans, the circadian factor facilitates activity during the day and inactivity during the night. The interaction between the two processes determines both sleep structure and sleep duration. The sleep structure is primarily dependent on accumulated sleep pressure (Process S), where high sleep pressure is associated with deeper sleep. Sleep duration is closely related to the sleep onset relative to the circadian curve (Process C). If the accumulated sleep pressure (Process S) aligns with a window of inactivity and sleep created by the circadian rhythm (Process C), sleep-propensity is high and both sleep structure and duration will likely be optimal (see Figure 2). Body temperature and sleep are closely connected as nocturnal sleep usually is initiated concurrent with a descending core body temperature, despite absence of time givers. Consequently, sleep propensity reaches its zenith when the body temperature reaches its nadir. Misalignment between the two processes may curtail sleep and will likely lead to reduced amounts of deep sleep [30]. This explains why shift workers may have trouble staying asleep when sleep is initiated at 10:00 h after a night shift. Because, although their sleep pressure is high, the sleep period coincides with an ascending circadian alerting signal. Folkard and Åkerstedt [31] proposed an additional process W (the waking-up effect), accounting for the drop in alertness that follows the sleep to wake transition, including sleep inertia.

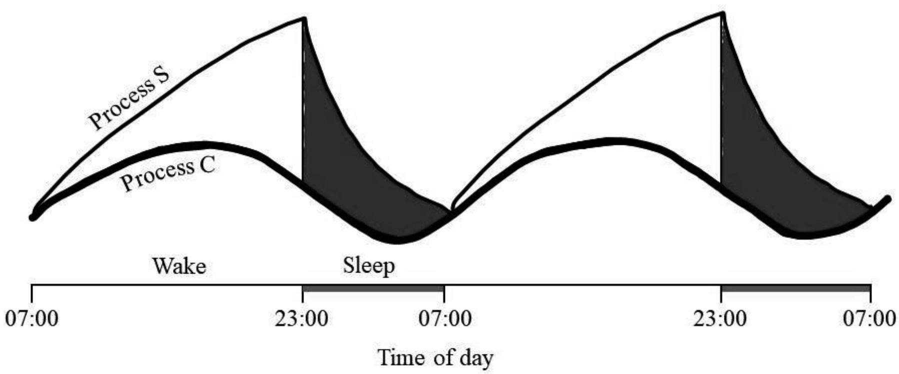

Figure 2. An illustration of the two-process model of sleep regulation. Process S illustrates built-up sleep pressure and Process C represents regular oscillations comprised by the circadian rhythm [29,30].

Sleep changes throughout life, both in duration and architecture [28, 32]. The average adult obtains 6-8 h per night [33]. Knowledge about the consequences of curtailed sleep formed the basis for adult sleep length recommendations of 7-9 h every night [34]. However, there seem to exist interindividual differences in sleep need (i.e., long- and short-sleepers) [35]. Furthermore, sleep is subjected to external disturbances illustrated by studies revealing curtailed sleep on workdays and oversleeping on non-workdays [28, 36]. Shift work, especially night work, represents a setting where the occupational demands coincide with the optimal window of sleep [37].

1.2.5 Sleep measurements

PSG is regarded as the gold standard of objective examination of sleep. However, PSG administration is quite demanding, costly, and the recording process may cause sleep disturbances [38]. For these reasons, it has in numerous areas been replaced by more flexible and cost-effective sleep tracking tools such as actigraphy, sleep diary, and tools based on radar technology (i.e., Somnofy). The actigraph is usually worn as a wristwatch and estimates sleep/wake patterns based on activity/inactivity measured by limb movement [38], while the sleep diary is an acknowledged subjective sleep assessment tool [39]. New technology such as sleep radars capture body movement based on the doppler principle and can additionally measure sleep architecture. With the sleep radars, sleep is scored with a separate algorithm which is validated against both PSG and actigraphy [40]. These tools provide data on sleep quality (i.e., sleep diary) and quantity and allow for sleep assessment in natural surroundings over an extended period, while being both less invasive and less expensive than PSG. Although the actigraphy and sleep diary do not enable reliable sleep staging, they provide useful parameters such as sleep timing, duration, and efficiency [38, 39].

1.3 Sleepiness

The adequacy of night-time sleep is only fully elucidated by complementary assessments of daytime sleepiness. Sleepiness is a multidimensional phenomenon that includes normal states as well as pathological symptoms. An acknowledged classification of sleepiness includes three main dimensions: physiological, introspective, and manifest [41, 42].

Physiological sleepiness or sleep propensity refers to the tendency to fall asleep, elicited by sleep restriction or deprivation [43, 44]. The first instrument that allowed for an objective assessment of sleepiness was the Multiple Sleep Latency Test [45, 46]. Since then, subjective measures such as the Epworth Sleepiness Scale (ESS) [47] have emerged to simplify examination of sleep propensity. Large intraindividual reliability over time in terms of sleep propensity have been found, indicating that individual variation on baseline levels operate independently of prior sleep time, and thus can be considered as a trait [48, 49]. Therefore, the ESS can be considered a subjective measure of *trait* sleepiness.

Introspective or subjective sleepiness refers to a perceived state of drowsiness that is sensitive to abrupt sleep-related changes, and correlates with decreased sleep duration, cognitive performance, and mood [50, 51]. One commonly applied assessment tool is the Karolinska Sleepiness Scale (KSS) [52], which allow for measurements of fluctuations in sleepiness in response to environmental factors (i.e., *state* sleepiness) [41]. The construct, assessed with the KSS, is validated against performance and physiological measures, as well as demonstrated to follow a diurnal pattern [53, 54]. The highest levels of sleepiness generally occur in the habitual night, when the core body temperature reaches its nadir, usually at 04:00-05:00 h [46].

The final dimension, manifest sleepiness, refers to the degree of sleepiness expressed behaviourally in interaction with environmental demands, such as increased reaction time [55, 56].

The quality and quantity of nocturnal sleep represent major determinants of daytime sleepiness, where fragmented and reduced sleep produce daytime sleepiness [57], which is prevalent in the general population. A study representative of the Norwegian population found a mean ESS score of 7, whereas the corresponding score among Norwegian shift working nurses was 8.1 [43, 58]. On this scale, a score of 10 or higher indicate excessive daytime sleepiness [47]. Misalignment between the sleep/wake period and the circadian rhythm, often experienced by shift workers (i.e., night shift) and travellers on long-haul flights (i.e., transcontinental), is associated with higher levels of sleepiness during waking hours. The consequence of these elevated sleepiness levels can be profound as they are associated with reduced performance and increased risk of accidents [59, 60]. Thus, sleepiness, the excessive and persistent kind, signals the individual to stop operating due to danger and life-threatening potential by continuing without sleep. Still, many persist to ignore these signals, both knowingly and unknowingly.

1.3.1 Fatigue

The similarities between sleepiness and fatigue contribute to an interchangeable use of the terms, sometimes even by professionals. Fatigue represents a multifactorial construct embodying distinctions between acute versus chronic fatigue, muscular versus mental fatigue, in addition to the debatable distinction between fatigue and sleepiness [61]. Acute fatigue is regarded as a normal response to insufficient recovery or demanding periods in life (i.e., temporary illness, emotional stress, or mental/bodily exertion), while chronic fatigue often is caused by illness or treatments. Acute fatigue ceases by sufficient rest, sleep, diet, and exercise, whereas chronic fatigue does not reside following the same countermeasures. Muscular fatigue refers to reduced muscle force caused by activity or exercise, while mental fatigue represents a psychological state caused by extended periods of cognitive strain. The latter is characterized by a body of symptoms such as subjective tiredness, decreased performance, impaired alertness, and worsened mood [61, 62]. It is challenging to remain consistent when faced with inconsistent use of the terms (mental) fatigue and sleepiness in aviation, when there are other terms for corresponding concepts in the fields of shift work and sleep. For instance, several studies from aviation discuss results of fatigue that have been measured by sleepiness scales [63]. Clarification and knowledge about the different subtypes are therefore important in operational settings to ensure that the workers have a concise conceptual understanding when they apply the terms to themselves. Further, research fields should also strive for concise use of concepts and terms – especially constructs that have been used interchangeably. Additionally, a straight line between terminology and instrument is essential to ensure good validity.

1.4 Sleep, sleepiness, and performance

The ability to perform is also greatly affected by curtailed sleep. Studies indicate that neurobehavioral dysfunction is positively associated with hours of wakefulness [64, 65], for example resulting in longer response time [66]. An American study found that 6 h of nocturnal sleep over 14 consecutive days resulted in cognitive performance equivalent to 24 h of total sleep deprivation. Furthermore, restricting sleep per night to only 4 h over 14 days resulted in performance levels corresponding to 48 h of total sleep deprivation. This indicates that even moderate sleep deprivation sustained over several days impair neurobehavioral functions. Interestingly, there was a substantial discrepancy between the sleepiness level indicated by the neurobehavioral performance and subjectively assessed sleepiness, where the participants evaluated their sleepiness to be less than the levels evident on the cognitive tests [51]. Thus, reaction time tests or vigilance tasks, such as Psychomotor Vigilance Task [67], have been applied to measure cognitive performance as an objective proxy for sleepiness.

1.5 Shift work and health

Shift work represents a well-known risk factor for deteriorated health as it interferes with several aspects of the workers life; it affects basic physiological function due to alterations of the innate sleep/wake cycle causing disturbance of the psychophysiological processes; performance and work efficiency as it follows oscillations over a 24-h span influencing the risk of accidents and errors; and health due to deteriorated psychophysiological processes. Numerous negative health effects of shift work, especially night work, has been documented. Deteriorated psychophysiological conditions may in short-term manifest itself as sleep disturbances, anxiety, depression, digestive problems, and performance deterioration. The long-term effects of shift work include increased risk of cancer, obesity, cardiovascular disease, reproductive dysfunction, gastrointestinal disorders, and diabetes [37, 68]. Several models illustrating the relationship between shift work, sleep and circadian rhythms, and short- and long-term effects exist [69, 70]. One model by Kecklund and Axelsson [69] can be applied to the traditional shift work force, while Merkus and colleagues [70] created a similar model that included additional factors such as time-of-day, working time duration, and recovery period. The latter model may be even more relevant as an explanatory model for the effects of shift work with both night work and long work hours (i.e., the HEMS workers).

1.5.1 Shift work, sleep, and sleepiness

The most reported and persistent health complaints reported by shift workers are sleep problems such as disturbed sleep, sleep loss, and excessive sleepiness [71]. The prevalence of shift workers who experience excessive sleepiness and insomnia range from 26 to 30% and 47 to 55%, respectively [72]. Shift workers' weekly sleep is approximately 10 h less than daytime workers and unintended sleep have been found to occur several times per month for 7% of workers on the night shift [71]. For a subset of shift workers, the schedule affects the sleep to such an extent that it develops into a disorder. If the above-mentioned symptoms are present over time and cannot be explained by other factors beside the shift schedule (i.e., other disorders, substance use, sleep hygiene), the shift worker may have developed chronic "shift work disorder" [73]. In a meta-analysis, the prevalence is estimated to 26.5% among shift workers, although there exist large differences between various shift work populations and shift schedules [74]. A study on oil rig workers who share some similarities to the HEMS workers, found the prevalence of shift work disorder to be 23.3% [75].

Night shift imply that the main sleep period falls on the biologic day, complicating sleep continuity. The sleep becomes more fragmented where the sleep stages N2 and REM are particularly affected, and the total sleep is reduced by 2-4 h. Further, early morning shifts (starting 06:00 h or earlier) have similar consequences with reduced sleep duration due to advanced waking and therefore particularly curtailing the REM sleep. These shifts have also been associated with reduced slow wave sleep due to anticipation of awakening difficulty, as well as increased sleepiness during the shift and throughout the remaining day [71, 76, 77]. The least sleep disturbances have been found for evening shifts, provided that shift-end time or commute do not delay the rest period [78].

The findings from a review suggested that long work hours are associated with sleep disturbances and reduced sleep time [79]. Kecklund, Sallinen, and Axelsson [11] found that shifts lasting 12 h or longer reduced the opportunity to obtain enough sleep between the shifts. On-call shifts are associated with disturbed sleep such as longer sleep onset latency, curtailed sleep, more fragmented sleep, and less deep sleep [80, 81]. Sleep duration recorded by actigraphy among on-call medical workers indicated a range in total sleep time from 2.8 to 4.8 h [82, 83]. Further, it has been suggested that the effects on sleep are linked to anticipation of a call and apprehension about missing a call [84].

However, shift workers differ to what extent they experience the aforementioned health issues or sleep problems, where some seem to tolerate the shift work setting better than others. Shift work tolerance is the ability to adjust to shift work without experiencing the detrimental consequences [85]. For instance, shift workers differ in their ability to sleep during the day, the extent of performance impairment due to sleep loss, and the degree of sleepiness during night shifts. Possible explanations for these differences include chronotype (i.e., morningness/eveningness), personality, gender, age, and genetics [85, 86]. Other person-level factors may also be involved such as sleep disorders, medication use, shift work history, and domestic responsibility [87]. However, the complete mechanisms behind these variations are complex and not fully uncovered [88].

1.6 Shift work, performance and safety

An incontrovertible link is established between shift work and reduced performance. The irregular sleep/wake cycle can impair alertness and performance substantially, affecting cognitive skills such as reaction time, communication, memory, and decision making [89]. The quality of performance parallels the circadian oscillations in body temperature, especially affecting shifts that coincide with the descending bodily temperature and concurrent optimal window of rest (i.e., night or early morning shifts) [37, 90]. Other shift work characteristics that are particularly related to decreased performance include long working hours and extended workweeks [91, 92].

Several review studies have examined the relationship between shift work and accidents [93, 94]. Folkard and Tucker [94] found that the risk of incidents (i.e., accidents and injuries) depended on type of shift, number of successive shifts, and hours on duty. The relative risk was found to be higher on the afternoon shift, but highest for the night shift, compared to the morning shifts. Corroborating results have indicated that night work was linked to increased accidental injuries [95]. For number of successive shifts, the risk rose gradually for each successive shift, accumulating in 36% higher risk on the fourth, compared to the first, night shift. Although smaller, the risk of incidents was also evident for successive morning/day shifts. Further, there was a gradual increased risk associated with hours on duty [94]. Results also suggested that extended workweeks (>55 h) were associated increased risk of incidents [93], while long shifts (>12 h) were associated with twice the risk associated with 8-h shifts. For the latter, the increased risk further accumulated over time [92, 96]. Increased numbers of quick returns have also been associated with increased risk of occupational accidents [97]. Moreover, an association exists between shift work injuries after workhours, i.e., traffic accidents, especially during the night and early morning hours [60, 98].

1.7 Air Ambulance Service

In the case of an emergency medical situation, time to treatment is crucial. Some treatments may be provided by paramedics and physicians on-scene, whereas some require multi-professional teams only available at hospitals. Consequently, the demand for an ambulatory prehospital system is present for two main purposes: (1) transport of physician to perform on-scene treatment, and/or (2) transport of patient to hospital. The air ambulance service can be subdivided into two types of ambulances: fixed-wing (i.e., planes) and rotor-wing (i.e., helicopter, HEMS). The planes are primarily used for long-distance patient transport, while helicopters may reach patients living in remote and geographically challenging places, and enable operations in almost any terrain [99, 100].

Historically, the use of helicopter as a lifesaving means of transport was first seen during the Korea war in the 1950s, further developed and successfully implemented during the Vietnam war in the 1960s. By enabling transport of wounded soldiers from war sites to medical facilities, the use of aeromedical evacuations contributed to the best survival rates of any war to that date [99, 101].

In Norway, the physician Jens Moe was a central force behind the development of the air ambulance service, driven by the drowning of a young boy named Bård Østgaard. In 1977, Moe founded the NAA and the Bård Østgaard Foundation, the latter was renamed The Norwegian Air Ambulance Foundation in 1980. The aim was to develop prehospital emergency medicine. Inspired by the German and Swiss prehospital emergency services, the Norwegian model included a small helicopter manned with a pilot, an HCM, and a physician, who all were on duty to ensure short response time [100].

Today, the workers at the NAA still ensure short response time by living together at a base, responding to missions around the clock and working long hours across the workweek. While other HEMS operators in Europe are organized in shifts lasting 12 h, 24 h, or 48 h, the NAA are one of few that have seven consecutive days shifts [102, 103]. Apart from the shift schedule, there are other differences among the HEMS operators; some commute daily to the helicopter base while others live on the base; and some operate at all hours while others only initiate missions during daylight. The Austrian HEMS operator Christophorus Flugrettungsverein (CFV) have a similar shift schedule as the NAA, but only initiate missions during daylight [104]. Consequently, compared to other HEMS operators, the NAA seem to have one of the more intensive work arrangements as they work for seven consecutive days and during these days take on missions at all hours.

1.7.1 Sleep and sleepiness in the HEMS

Although scarce and ambiguous, some sleep and sleepiness studies have been conducted on HEMS workers. During 24-h duties, American HCMs obtained on average 5.3 h of sleep in the night portion of their shift, ranging from 2-9 h. The lowest on-duty sleep reported by the workers the past month was approximately 2 h, whereas 3.8% reported no sleep prior to their 24-h shift the past month [105]. Nevertheless, these results could be subjected to recall bias as the respondents retrospectively reported their sleep from one month back. Dutch HEMS pilots working three consecutive 13-h shifts slept on average 5.9 h. Higher workload was related to impaired sleep quality, whereas distressing shifts were associated with increased sleep latency onset. The latter was mediated by perseverative cognition [102]. A study found no significant difference in skill performance between 12-h and 24-h shifts. The 24-h shift was expected to have decreased performance due to increased sleepiness levels [106].

1.7.2 Fatigue Risk Management System

Fatigue Risk Management System (FRMS) is a part of occupational sleep medicine developed to consider the interplay between physiology and performance (i.e., circadian rhythm and sleep drive). FRMS has been defined as a scientific, data-driven process that use systematic methods to gather information in order to monitor and manage risks associated with fatigue-related errors [107]. Closely related are safety regulations that have been created to attenuate the risk of sleepiness and fatigue in safety-sensitive industries. For example, prescriptive hours-of-service regulation have been implemented, imposing a priori boundaries intended to reduce risk by specifying shift duration and between-shift intervals [108]. In HEMS, such regulations include flight and duty time limitations, specifying hours of flight time and active duty time at different intervals (i.e., 24 h, 48 h, 72 h) [109].

2. Rationale and research aims

Several studies have documented the relationship between shift work and its negative effects on sleep and sleepiness. The HEMS crews work seven consecutive days in which they take on missions at all hours. However, the research conducted on shift working HEMS crews is scarce and knowledge about the effects on sleep and sleepiness in this group is limited. Consequently, given this occupations' inherent safety-sensitive nature, studies addressing these gaps of knowledge are essential. Additionally, the NAA established a FRMS in 2014 for which the generated data served as necessary baseline information.

2.1 Overall aim of the thesis

The overall aim of the thesis was to provide more knowledge about the effects of shift work and long work hours on sleep and sleepiness among personnel working in the HEMS.

2.1.1 Aim of Paper 1

The main aim of Paper 1 was to examine sleepiness (measured both subjectively and objectively) among shift working pilots and HCMs over three consecutive weeks: the week before work, the workweek, and the week after work. Specifically, we hypothesized that sleepiness would be higher during the workweek, compared to the week before and after work. Furthermore, we hypothesized that sleepiness would increase during the workweek and towards the end of the workday. Finally, we expected number of missions and duration of missions to be positively associated with sleepiness scores.

2.1.2 Aim of Paper 2

The main aim of Paper 2 was to examine how shift working pilots and HCMs slept (measured both subjectively and objectively) during their workweek, and whether this varied between a season with fewer missions (Wave 1) and a busier season with more missions (Wave 2). We also examined the workers' sleep over three consecutive weeks: the week before work, the workweek, the week after work, in both seasons separately. Furthermore, whether number of missions and duration of missions affected the sleep variables was also examined.

2.1.3 Aim of Paper 3

The main aim of Paper 3 was to examine sleep (measured both subjectively and objectively) and sleepiness in shift working HEMS pilots in two European countries working a similar shift schedule. Changes in sleep and sleepiness over time during the workweek and differences in sleep and sleepiness between the countries were examined. Furthermore, number of missions and duration of missions were examined in relation to the sleep and sleepiness variables of the two pilot groups.

The NAA and CFV are, to the project groups' knowledge, two of the few HEMS operators in Europe with a seven consecutive days shift schedule. As there were certain differences in the two operators' work characteristics, independent of the shift schedules, an examination of both increases our knowledge about the interplay between the work setting and sleep. For this reason, the two HEMS operators were examined in Paper 3.

3. Methods

3.1 Procedure

The data collection was conducted on pilots and HCMs working for the Norwegian Air Ambulance (NAA) in Norway and pilots working for the Christophorus Flugrettungsverein (CFV) in Austria. Paper 1 and Paper 2 were conducted on the pilots and HCMs working for the NAA. Paper 3 was conducted on the pilots working for the NAA and CFV.

The data was collected from the NAA during the fall and winter of 2014 (Wave 1) and spring and summer of 2015 (Wave 2). From the CFV, data was collected during the spring and summer of 2016. All three data collection periods lasted for three consecutive weeks: the week before work, the workweek, and the week after work.

The shift schedule in the NAA consists of a 7-d workweek followed by a 14-d off work period, then a new 7-d workweek followed by a 21-d off work period. The workweek started and ended at 10:00 h on the first and seventh duty day, respectively. During the workweek, the workers at the NAA initiated missions at all hours throughout the year. The crew (pilot, HCM and anaesthesiologist) lived together on the base during the workweek, which was equipped with all essential facilities, including single bedrooms with enclosed bathrooms.

In the CFV, the shift schedule consists of a 7-d workweek followed by a 7-d off work period, then a new 7-d workweek followed by a 7-d off work period. The workweek started and ended at sunrise (06:00 h earliest) and sunset (21:00 h latest) on the first and seventh day, respectively. During the workweek, the CFV workers only performed missions that were initiated at daylight. The CFV crew lived together on the base during the workweek, however, those who lived less than 30 min from the base could spend the nights at home.

While on duty, the crews operated according to flight and duty time limitations approved by the Norwegian Civil Aviation Authority for the NAA and the Austrian National Aviation Authority (Austro Control) for the CFV.

3.2 Participants

3.2.1 Study 1

In 2014/2015 the NAA operated on 9 bases in Norway. All pilots and HCMs (N = 70) working at the NAA bases were invited to participate. In all, 61 (87%) took part in Wave 1. Due to changes in work tasks that were inconsistent with the remaining sample, two were not invited to participate in Wave 2. Thus, 59 workers (29 pilots and 30 HCMs) were invited to take part in Wave 2. In all, 25 pilots and 25 HCMs participated, yielding a response rate of 85%.

3.2.2 Study 2

In Austria, the study was conducted during the spring/summer of 2016. Based on a representative sample comprised of urban and rural bases, 24 CFV pilots were invited to participate in the study. In total, 22 (92%) of the invited CFV pilots took part in the data collection.

3.2.3 Samples and procedures of Paper 1

Paper 1 was based on three-week data from Study 1, Wave 2. In total, the sample consisted of 25 pilots and 25 HCMs working for the NAA.

3.2.4 Samples and procedures of Paper 2

Paper 2 was based on three-week data from both waves in Study 1, including pilots and HCMs working for the NAA. The sample consisted of 25 pilots and 25 HCMs who participated in both waves.

3.2.5 Samples and procedures of Paper 3

Paper 3 was based on data from Study 1 and Study 2. From Study 1, the data derived from Wave 2 where only the pilots were included. Data derived from the workweek, and the sample consisted of 25 NAA pilots and 22 CFV pilots.

3.3 Instruments

3.3.1 Subjective instruments

Questionnaire

A questionnaire covering demographic and background information was completed on the first duty day. It contained information regarding age, sex, children living at home, marital status, position (pilot/HCM), years in position (y), second jobs, means of commute, commute length, day of commute, nicotine use (smoke and/or snuff, yes/no), caffeinated drinks consumed at work (number of cups), physical health (1 = very good, to 5 = very poor), chronotype (1 = pronounced morning type, to 5 = pronounced evening type), sleep need (h), use of sleeping aid (yes/no; which), sleep problems related to work schedule (1 = no, to 5 = very much), degree of sufficient sleep at work (1 = never, to 5= very often), and frequency of workweeks with less than 5 h of sleep (1 = every workweek, to 4 = occasional workweek).

Epworth Sleepiness Scale (ESS)

The ESS [47] is an 8-item scale measuring trait sleepiness, administered on the first duty day. It describes 8 situations in which the participants estimate the likelihood of dozing off or falling asleep, rated on a 4-point scale. The composite scores range from 0-24, where scores above 10 indicate excessive daytime sleepiness. Cronbach's alpha reliability of 0.84 calculated for Paper 1 indicated good internal consistency.

Accumulated Time with Sleepiness (ATS)

The ATS [110] measure state sleepiness and was completed by the NAA workers once every day throughout the three-week data collection in Wave 2. It is designed to measure subjective sleepiness over longer periods of time. The participants estimated the occurrence and duration of sleepiness symptoms during the wake period, ranging from 0%-100%. A 6-item version of the ATS was applied in the present study, including the items "heavy eyelids", "feeling gravel-eyed", "difficulty in focusing your eyes", "irresistible sleepiness", "reduced performance", and "periods where you were fighting sleep". For each item, mean scores of weeks and days were calculated, and Cronbach's alpha reliability of 0.92 calculated for Paper 1 indicated good internal consistency.

Karolinska Sleepiness Scale (KSS)

The KSS [52] is a 9-point scale that measure state sleepiness and was completed every other hour while awake during the workweek. Subjective sleepiness is rated from 1 = very alert, 3 = alert, 5 = neither alert nor sleepy, 7 = sleepy but no problems staying awake, to 9 = very sleepy, fighting seep, effort to stay awake. The scale also consists of the non-verbally anchored scores 2, 4, 6, and 8. Excessive sleepiness is indicated by a score of seven or higher. Mean scores were calculated for every workday and for every two hours of the wake period (08:00-00:00 h) during the workweek.

Sleep diary

The participants filled out daily estimates of their sleep periods in a modified version of a sleep diary [111]. The diary was completed upon rise time in the morning during all three weeks of each data collection period. From the sleep diary several sleep variables were extracted including bedtime, wake-up time, wake after sleep onset, time in bed, total sleep time, and sleep efficiency (total sleep time/ time in bed × 100).

3.3.2 Objective instruments

Reaction time test

As an objective measure of sleepiness, a reaction time test based on the Posner-cue-target paradigm was administered [112, 113]. In addition to response time, it also measured accuracy and inhibition, and was programmed with E-Prime 2.0 (Psychology Software Tool). The NAA workers completed the test five times during the workweek: in the evening of the first workday, morning and evening at midweek, and morning and evening at workweek-end. The task was administered on a laptop and the workers were instructed to complete the test while taking a comfortable position in calm surroundings. The test screen consisted of two rectangular frames with a crosshair between, where the participants were instructed to fixate on the latter

(Figure 3). They were further instructed to respond as fast as possible by pressing the 'D' or 'L' key when the target stimulus appeared in either the left or right frame, respectively. Intermittently, the frame on one of the rectangles would broaden (i.e., a cue) prior to the appearance of the target stimulus, which the participants were instructed to ignore. Three categories were integrated in the test: "no cue", "valid cue", and "invalid cue". The "no cue" category implied appearance of the target stimulus in one of the frames in normal conditions (i.e., no broad frames). "Valid cue" entailed that the target stimulus appeared in the broadened frame, whereas the target stimulus appeared in the opposite to the broadened frame in the "invalid cue" category. The test duration was 4 min and 40 s in which 168 target stimuli were presented. The cue would appear 200-400 ms prior to the target stimulus which was presented for 500 ms. The rest intervals were randomized and lasted between 600-1400 ms. The target stimuli were distributed over 66.6% for "valid cue", and 16.7% for both "no cue" and "invalid cue". The test generated response time and response accuracy for all three categories.

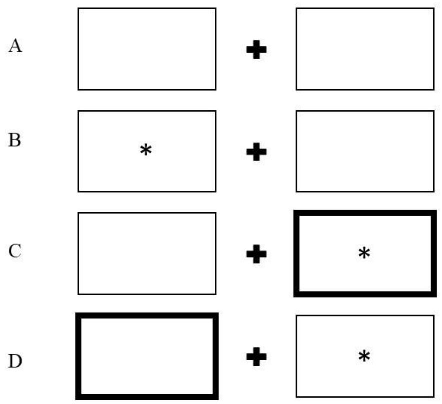

Figure 3. An illustration of the different conditions of the reaction time test. (A) representation of the test screen before start, (B) the "no cue" condition, (C) the "valid cue" condition, and (D) the "invalid cue" condition.

Actigraphy

Actigraphs (Actiwatch 2, Respironics Inc., Cambridge, MA, USA) were worn continuously during all three weeks in all data collection periods. An actigraph has the size and appearance of a wristwatch and conduct continuous recordings of movement and time [114]. Based on the amount of movement and activity, estimates of sleep and wake profiles are generated by algorithms. The individual profile was recorded by 1 min epochs and the threshold for sleep/wake detection was set to medium (default), provided by the Actiware software. The medium setting includes a sensitivity threshold at 40 counts of activity per epoch for wake detection, whereas for sleep start/end the threshold was 10 min of inactivity/activity. The scoring was based on a hierarchical approach proposed by Chow and colleagues [115]. The first step emphasizes event markers and activity levels to determine sleep time, followed by sleep diary and activity level in absence of event markers. Sleep variables that were calculated by the Actiware software included bedtime, wake-up time, time in bed, wake after sleep onset, total sleep time, and sleep efficiency.

Mission log

A daily overview of number of missions and duration of missions for the individual worker was provided by both the NAA and CFV staff. The duration of missions was recorded from the time an alarm started to the time the helicopter landed back at the base. The NAA also conducted training sessions during the workweek, and these data were included in the variables to calculate the total workload. For Paper 1 and Paper 2, categorical variables based on tertiles were created for number of missions and duration of missions. Missions taking place between 00:00 and 07:00 h, including missions that were initiated before midnight but completed after, were defined as night missions. However, missions that were initiated before 07:00 h but completed after (i.e., 08:00 h) were not defined as a night mission.

See figure 4 for an overview of when each instrument was applied.

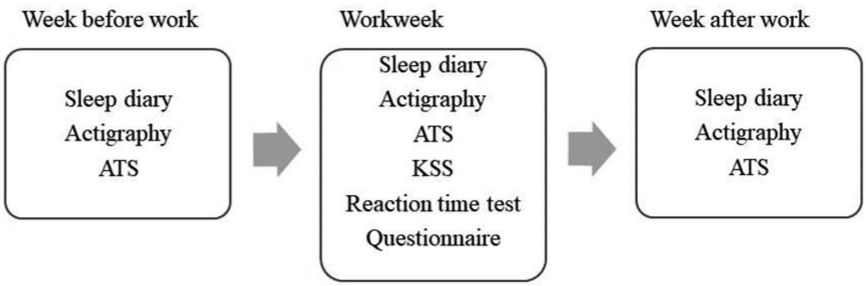

Figure 4. An overview of instrument allocation over 3 weeks of data collection.

3.4 Statistical analyses

3.4.1 Paper 1

IBM SPSS Statistics, version 25 (IBM Corp., USA), were used to conduct the statistical analyses. To explore changes in the outcome variables over time, a linear mixed model (LMM) approach was applied for the ATS, KSS, response time, and response accuracy. The analysis of ATS over three weeks included week (1-3) as a fixed factor, where the second week (workweek) was set as reference. In the analysis of ATS during the workweek, day (1-7), number of missions (lower, medium, higher), and duration of missions (lower, medium, higher) were modelled as fixed factors. Day 1, medium category in number of missions, and medium category in duration of missions were entered as references categories. For the analysis of the KSS scores during the workweek, day (1-7), time of day (08:00-00:00 h), number of missions (lower, medium, higher), and duration of missions (lower, medium, higher) were set as fixed factors. Day 1, 00:00 h, medium category in number of missions, and medium category of duration of missions were set as references. Bases were adjusted for in all the latter analyses. In the analyses of response time and response accuracy, the test points (1-5) were entered as fixed factors where the last test point was set as reference. Subjects were modelled as random factor in all the latter analyses. Regression coefficients (unstandardised b-scores) were reported. The significance level for all analyses was set at $p < 0.05$.

3.4.2 Paper 2

IBM SPSS Statistics, version 25 (IBM Corp., NY, USA), was used for the analyses. LMMs were applied in order to evaluate the following outcome variables over time (measured by sleep diary and actigraphy): bedtime, wake-up time, time in bed and total sleep time. In the analyses, the outcome variables in the workweeks of Wave 1 and Wave 2 were compared, and the sleep patterns were analyzed over three consecutive weeks (week before work, workweek, week after work) for Wave 1 and Wave 2, individually. Where suitable, the number of missions (lower, medium, higher) and duration of missions (lower, medium, higher) were included as fixed factors, with medium category as reference. In the analyses over three weeks, week (1-3) was entered as fixed factor with the second week (workweek) as reference. For the latter analyses, regression coefficients (unstandardised b-scores) were reported. Due to skewed residuals, the sleep variables wake after sleep onset and sleep efficiency were analysed with Mann-Whitney U tests when comparing the two workweeks (Wave 1 versus Wave 2). A Friedman ANOVA with Wilcoxon post-hoc test was conducted for examination over the three consecutive weeks (in both waves), as well as Bonferroni corrections for multiple testing. For the latter analyses, z-scores were reported. Alpha values less than .05 were considered statistically significant.

3.4.3 Paper 3

All statistical analyses were conducted using Stata 16.1 (StataCorp, College Station, TX, USA). Due to low sample size and tables containing cells with a frequency less than five, Fisher's exact test was conducted to explore differences between the NAA and CFV in terms of sex and sleep problems. Student's t-tests were applied to compare differences in age, sleep need, and caffeine intake, whereas a Mann Whitney U test was used to explore differences in median values of years in position between the NAA and CFV. The latter was also used for analyses of number of missions and duration of missions. LMMs were applied to explore the sleep and sleepiness variables during the workweeks, for the NAA and CFV, combined and separately. The outcome variables measured by both sleep diary and actigraphy included bedtime, wake-up time, wake after sleep onset, time in bed, total sleep time, and sleep efficiency. The outcome variable for exploring sleepiness was the KSS. For the analyses on the workweeks, day (1-7) and time (only KSS; 08:00-00:00 h) were entered as fixed factors with day 1 and 08:00 h as reference categories. Subjects were included as random factor in all the analyses, whereas number of missions and duration of missions were modelled as covariates. The significance level was set at $p < 0.05$.

3.5 Ethics

The project was reviewed and approved by the Regional Committee for Medical and Health Research Ethics of Western Norway, health region West (project number 2014/593). No additional ethical approval was required by the equivalent Austrian authorities (415-EP/73/671-2016). It was conducted in accordance with the Declaration of Helsinki. Together with the materials in the first data collection period the workers received a letter describing the aim of the study, as well as informed consent which was signed and returned with the completed materials. The letter also contained information about confidentiality and option to withdraw at any time throughout the study period. Upon enrolment, each participant was given a unique code that was used throughout the data collection period. The coding key, which linked the unique code to each participant, was kept separate from the data and password-protected.

4. Results

4.1 Paper 1

The main finding suggested that the overall sleepiness levels were low during the three-week data collection period (Wave 2). Within these levels of sleepiness, some differences were evident over the three weeks and during the workweek. The sleepiness scores measured by the ATS was significantly lower during the workweek (week 2), compared to the weeks off work on all six ATS items: heavy eyelids, feeling gravel-eyed, difficulty in focusing your eyes, irresistible sleepiness, reduced performance, and periods where you were fighting sleep (see Table 2 in Paper 1 for corresponding statistics). Consequently, the first hypothesis was rejected, postulating that sleepiness would be highest during the workweek, compared the weeks off work.

The sleepiness scores measured by the KSS was significantly higher on the first workday ($M = 3.23$) compared to the remaining workdays ($^{\text{day 2}}M = 2.76$, $p < 0.001$, $^{\text{day 3}}M = 2.94$, $p < 0.01$, $^{\text{day 4}}M = 2.82$, $p < 0.001$, $^{\text{day 5}}M = 2.88$, $p < 0.001$, $^{\text{day 6}}M = 2.94$, $p < 0.01$, $^{\text{day 7}}M = 2.91$, $p < 0.001$). Therefore, the second hypothesis, stating that sleepiness would increase throughout the workweek, was rejected. Further, the sleepiness levels were higher at midnight compared to all other hours of the workday (see Table 4 in Paper 1 for corresponding statistics), supporting the third hypothesis. The workers with most missions had lower sleepiness scores, while the workers who spent most time on missions had higher sleepiness scores, both compared to the medium category. These results partly supported the fourth hypothesis which stated that having higher number of missions and spending more time on missions would be associated with higher sleepiness levels compared to those in the medium category. No significant difference was evident for neither response time nor response accuracy during the workweek.

4.2 Paper 2

Overall, the results indicated that the workers' sleep was somewhat altered during the workweek compared to the weeks off work. Bedtime was significantly later during the workweek in the season with more missions (Wave 2) compared to the workweek in the season with fewer missions (Wave 1) ($^{diary}\beta = -0.36, p < 0.001$, $^{actigraphy}\beta = -0.34, p < 0.01$). Further, the workers spent more time in bed (measured by diary) during the Wave 1 workweek compared to the Wave 2 workweek ($\beta = 0.26, p < 0.05$). The number of missions and duration of missions were significantly higher during Wave 2 compared to Wave 1. In Wave 2, workers who spent more time on missions had later bedtime ($^{diary}\beta = 0.59, p < .001$, $^{actigraphy}\beta = 0.53, p < .01$), while the workers with most missions spent less time in bed (only for sleep diary: $\beta = -0.61, p < .05$). No difference was evident between the two workweeks for neither wake-up time, wake after sleep onset, sleep efficiency nor total sleep time. The workers obtained over 7 h of nightly sleep during the workweek in both waves, measured by sleep diary.

The worker's sleep period was more delayed during the workweeks, when comparing to the weeks off work in both waves. The workers also spent more time in bed during the workweek compared to the weeks off. However, they spent more time awake after sleep onset and sleep efficiency measured with actigraphy was lower during the workweeks compared to the weeks off work. The subjective total sleep time was higher during the workweek compared to the weeks off in Wave 1 (see Table 2 in Paper 2 for corresponding statistics).

4.3 Paper 3

The main findings indicated that both pilot groups obtained appropriate amounts of sleep during their workweek, although some differences between the two groups were evident. The results for both pilot groups combined (NAA and CFV), indicated a consistent sleep period during the workweek with a slight delay as they approached workweek-end. Although there were some discrepancies between the results derived from sleep diary and actigraphy, the overall results for the pilot groups individually suggested some notable differences. The NAA pilots had fewer missions, drank more caffeinated beverages, and were less experienced compared to the CFV pilots. Further, the NAA pilots' sleep period was more delayed, they spent more time in bed and slept longer than the CFV pilots during the workweek. However, the NAA pilots also spent more time awake after sleep onset and had lower sleep efficiency compared to the CFV pilots (see Table 2 in Paper 3 for corresponding statistics). The duration of missions was positively associated with a later sleep period for both pilot groups (see Table 3 in Paper 3 for corresponding statistics). All sleepiness levels remained low for both pilot groups during the workweek, although slightly elevated levels during the first workday compared to the following workdays were found. The sleepiness scores over the course of a workday resembled a slight U-curve with a steady increase approaching midnight (See Table 4 in Paper 3 for corresponding statistics).

5. Discussion

5.1 Low sleepiness and adequate sleep length

Despite having a work schedule that included consecutive shifts and long work hours, the pilots and HCMs seemingly coped well with their work schedule in terms of sleep and sleepiness. This is contrary to the findings of numerous shift work studies on various occupational groups where sleep problems and high levels of sleepiness have been found [9, 60]. The HEMS crews (i.e., pilot and HCM) were also susceptible for workload and workhours similar to quick returns and unfortunate placement of workload that could resemble counterclockwise rotating shifts (i.e., morning work followed by night work with less than 11 h between), both associated with shortened sleep and increased sleepiness [116, 117]. However, nurses in the latter studies may have had more predicable workhours, compared to the HEMS crew for which the actual workhours and workload may be more intermittent during the workweek [11]. Although, our findings are in line with studies on certain occupational groups that seem to cope well with shift work settings similar to those of the HEMS crews. For instance, a study on airline pilots with compressed work periods found adequate sleep length (at least 6 h) [118]. Further, studies on oil rig workers found that the employees experienced relatively low levels of sleepiness and obtained sufficient amounts of sleep (on average 6.5–7.0 h of sleep) when working 12-h shifts for 14 consecutive days [119, 120]. Corroborating results were also found for construction workers working long hours in an isolated environment 78 degrees North [121]. Similar to the HEMS crews, the workers in the two latter studies lived on-site and were thus protected from domestic responsibilities during their work period. Although different from the HEMS crews in predictability of workload and workhours, the comparison is still useful. This notion is corroborated by findings from a pilot barometer where 50% of French pilots considered inadequate rest areas during the duty period as a contributor to fatigue [122].

In an American study, HEMS nurses reported that 18-h shifts compared to 12-h shifts during a 72-h duty schedule were more compatible with their off-work lifestyle. [123]. Several factors affect sleep during the off-duty period, including commute, meals, leisure, personal hygiene, as well as general domestic and social responsibilities. Shorter shifts grant shorter off-duty periods, in which all of the above must be fitted. For the HEMS workers at the NAA, the workweek was accompanied by an off-work period of at least 14 days, providing the workers with more time to manage the above-mentioned factors. The sleep and sleepiness levels on the weeks off could indicate that the recovery period between the workweeks were sufficiently long to counteract the effects of the long hours, and thus function as a protective force. This is in accordance with results from a barometer where 88% of Danish airline pilots attributed insufficient rest between work periods as a cause of fatigue [122]. These longer periods of free time between the long shifts could also have contributed to a preference for such schedules, similar to the findings of Thomas and colleagues [123]. Thus, the HEMS workers may have been motivated to function optimally in their work settings in order to preserve such shift schedules.

During the workweek, the HEMS crews adhered to flight and duty time limitation that regulated maximum flight time and active work time. If they exceeded these limits, the HEMS crews had to remain off-duty, but on-site, for a minimum of 8 h. This rest period is below the recommended minimum of 12 h [11], but still seem to be sufficient given the present study's results. Good sleep facilities, short travel time, and few domestic obligations have been pointed out as explaining factors of how shorter-than-recommended rest periods still could allow for sufficient restitution [119]. However, we do not have data on to what extent the HEMS crews reported off-duty due to reaching maximum flight or work time levels during the data collection periods.

5.2 Disturbed sleep

Health complaints related to sleep disturbances (i.e., fragmented sleep and low sleep efficiency) are frequently reported by shift workers [124]. In addition to low sleepiness and adequate sleep length, the results also showed that the NAA workers spent more time awake after sleep onset and had lower sleep efficiency during their workweek compared to the weeks off work. Additionally, the results from Paper 3 indicated that the NAA pilots had more disturbed sleep compared to the CFV pilots.

Studies have indicated that disturbed sleep may be less restorative and associated with daytime sleepiness, as well as deteriorated performance [125, 126]. Disturbed sleep is a common problem in subjects who suffer from sleep disorders such as sleep apnoea, but is also present in healthy individuals [127, 128]. In addition to taking on missions during the night, which can explain why the sleep was more interrupted, the on-call setting has also been found to affect sleep negatively independently of actual night work [129]. In a recent on-call study, 56% of the participants reported that simply being on-call impacted their sleep, even when no calls were received [130]. Although statistically significant, one should keep in mind that the overall differences were small. For instance, in Paper 2 the differences in minutes spent awake after sleep onset across the weeks were not even evident when represented by median scores (asymmetric data). Further, the differences also varied depending on the instrument applied, as for the sleep efficiency which was only significantly lower during the workweek when measured by the actigraph (in Paper 2). The effects of disturbed sleep for the HEMS crews were delimited to the workweek and therefore temporary. Additionally, the HEMS crews included in our study represent a highly selected group with good general health who complete regular health checks. In healthy individuals, findings indicate that two full nights of sleep are required for recuperation [59]. As the (NAA) HEMS crews had a minimum of 14 days of recovery time between the shifts, this may be sufficient for the workers to recuperate even after particularly busy workweeks exceeding the sleep disturbances measured in the present study. Hence, together with the findings of low sleepiness levels and short response time (although high missing rate), there is reason to believe that the detrimental effects of such sleep disturbance are manageable for the HEMS crews.

5.3 Cognitive performance

Reduced sleep and elevated sleepiness are associated with a degrade in cognitive performance, such as slowed response time [124]. The reaction time test results indicated that the NAA workers maintained short response time and high response accuracy throughout the workweek. Nevertheless, the reaction time test had 43% missing responses suggesting that the risk of making a type II error (i.e., false negative) is present and the results must be interpreted with prudence. The reason for such high numbers of missing may be linked to the ecological field setting. The test could neither compromise the HEMS operations nor the workers sleep opportunities. For these reasons, it could be challenging to prioritize completing tests such as the present. Still, in order to objectively examine how the cognitive performance is affected by the work schedule, such tests should not be excluded from field studies. However, there may be potential for improvement in the test setup and platform. For instance, changing the platform from a stationary computer to a handheld device or via the workers' smartphone, could potentially increase the amount of completed tests. Still, this would imply diminished control of the test surroundings.

The test used on the NAA workers lasted 4 min and 40 s, which may not have been sufficiently long in order to elucidate the potential detrimental effects of sleepiness. A study suggested that the unmasking effect of sleepiness and sleep deprivation increased along with test length, implying that our test failed to detect underlying sleepiness [131]. Therefore, increased test duration could potentially help uncover fluctuations in sleepiness and performance, but there are also studies concluding that shorter test duration (i.e., 5 min) is a reasonable substitute in contexts where a longer test is challenging to implement [132]. As there were no indications of elevated sleepiness levels based on the subjective sleepiness scales, one could conclude that opposing results were unlikely for the reaction time test. However, discrepancies between subjective and objective measures of sleepiness have been found, where subjects estimated lower sleepiness levels compared to the corresponding decline in performance indicated by objective measures [51]. The discrepancy between subjective and objective measures of sleepiness may be explained by reduced sensitivity to sleepiness, most pronounced in individuals with sleep disorders [57]. Physiologically alert individuals were more accurate in their estimations of sleepiness following a night of sleep restriction [133]. Thus, as the HEMS workers are healthy individuals, they may be somewhat protected against the latter gap.

The type of test also holds some strengths compared to other types of reaction time tests. While reaction time tests such as the Psychomotor Vigilance Task (PVT) only assess non-executive function by measuring the speed of a subject's automatic response to a visual stimulus (Go task), the Posner paradigm-based test included in our project additionally assess executive function by measuring response inhibition (Go-NoGo task) [67]. Response inhibition is comprised by a cognitive process where the individual must prevent itself from carrying out an inappropriate prepotent response. This involves two cognitive elements: (1) perception of incoming stimuli and (2) avoidance of automatic reaction [134]. The effects of total sleep deprivation on these executive and non-executive functions have been tested over 64 h. The results indicated a decline in correct hit rate (Go) after 55 h, but the inhibitory capacity (NoGo) was reduced after only 23 h, suggesting that the inhibitory response is more sensitive to sleep deprivation or sleepiness compared to the automatic response [135].

5.4 Subjective and objective discrepancy

A consistent finding in Paper 2 and Paper 3 was the discrepancies between sleep measured by actigraphy and sleep diary. Compared to the sleep diary data, sleep measured with actigraphy resulted in consistently lower sleep efficiency and sleep length, and higher wake after sleep onset. Such low coherence represents a common finding in research applying both instruments [136-138]. Three ways to interpret the implications of these results are: (1) the workers under-reported the time they spent awake after sleep onset in the sleep diary, which also explains the discrepancies in sleep length and sleep efficiency, or (2) the actigraphs were too sensitive and measured awakenings when the workers actually slept, or (3) a combination of both. Between the two instruments, it is challenging to know which can best elucidate the "real" sleep or which should be emphasized the most. While actigraphy has the weakness of solely being based on movement, the sleep diary is subjected to response biases that follow subjective self-report. However, one may argue in favour of emphasizing subjective sleep as self-assessment of prior sleep period and daytime functioning is the core of evaluating whether one has obtained sufficient amounts of sleep or not – the feeling of being rested [139]. An example from the sleep disorder paradoxical insomnia also adds to this argument. In this type of insomnia there is considerable sleep discrepancy, where contrary to the subjectively reported sleeplessness, the PSG reveals close to normal sleep patterns [140]. Still, these patients receive treatment because of the subjectively appraised insomnia [141].

In normal, healthy adults the actigraphy has proven to provide accurate sleep estimates, where the reliability of these estimates is positively associated with study length [38, 142]. Further, to manage the response biases accompanying subjective instruments, the actigraph could be a useful addition. Subjective sleep measured by the sleep diary is also widely used and regarded as a valuable tool for sleep assessment. Studies have found that sleep diary entries of at least seven consecutive days provide reliable sleep estimates in adults [143], a criterion fulfilled in our study. Moreover, when examining someone's sleep, the subjective aspect of perceived sleep and self-assessment of prior sleep periods is important to incorporate. For these reasons, the combination of both subjective and objective measures provides nuanced and valuable insight into the participants' sleep periods.

5.5 Two HEMS operators

In Paper 3, we examined sleep and sleepiness in two different HEMS operators: the Norwegian Air Ambulance (NAA) in Norway and Christophorus Flugrettungsverein (CFV) in Austria. These HEMS operators were similar in terms of the shift schedule, but different regarding certain work characteristics. While the NAA pilots initiated missions at all hours during their workweek, the CFV pilots only took on missions during daylight. Further, while the NAA pilots had to live on the base during the entire workweek, the CFV pilots who lived in proximity to the base could spend the nights at home.

We found differences between the pilot groups on all included sleep variables. The NAA pilots had a more delayed sleep period, spent more time awake after sleep onset, had lower sleep efficiency, but spent more time in bed, and slept longer than the CFV pilots. However, we also found that the pilot groups obtained appropriate amounts of sleep during their workweek. For this reason, Paper 3 provided us with information about this particular shift schedule and how sleep was affected by the work setting as a whole, in addition to pointing us in a direction on how operator-specific differences contributed to these sleep fluctuations. Nevertheless, as our results derived from field studies, we had limited access to all variables that interacted with the results, and there are thus considerable uncertainties related to precisely what affected our results. However, our perception is that a comparison between the HEMS operators *including* their differences has provided us with additional knowledge on this field.

A salient finding in Paper 3 was the convergence of several sleep variables on the last duty day. On the final workday, the NAA pilot woke up earlier, spent less time in bed, and slept less compared to the previous workdays. The CFV pilots woke up later, spent more time in bed, and slept longer compared to their prior workdays. These results may be explained by the time of crew change. As the CFV pilots only conducted missions during daylight, the crews could spend the night at home after the last workday, explaining the sudden change. The NAA, on the other hand, remained on duty during the night and had to be ready for change of crews at 10:00 h on the next morning, which could explain their change in sleep.

5.6 Methodological considerations

5.6.1 Instruments

The objective instruments require some reflection. The actigraph enabled a non-intrusive assessment of sleep in the workers' natural surroundings, both at work and home. Its flexibility and cost-effectiveness also allowed for collection of sleep data on multiple workers simultaneously over an extended period. However, the basis for sleep estimation by actigraphy is movement (i.e., accelerometer), thus representing a considerable limitation. Generally, actigraphy has been proven to overestimate sleep in specific study populations, and cautions use is advised for populations with specific sleep disturbances. Still, it is regarded as a reliable and valid tool for examining sleep in normal, healthy populations [38, 144]. Considering sensitivity and specificity, actigraphy is reported as reasonably good at detecting sleep (sensitivity), but also to have a relatively poor ability to detect wake (specificity) [145, 146]. Thus, there is also need for caution in comparisons of results from different devices and populations, as the estimated sleep has varied considerably depending on type of device used, settings applied, and study population [38, 146]. Innovative development of microwave biomedical radars has resulted in sleep radars that enable non-intrusive and contactless sleep monitoring which has been validated against PSG [40, 147]. As these radars enable high accuracy sleep staging, they could provide nuanced knowledge about the workers' sleep. However, they do not provide information about activity and sleep that take place outside the bedroom.

The reaction time tests enabled assessment of cognitive performance in the natural surroundings by use of computers. However, it was challenging to successfully implement a performance task as an objective proxy for sleepiness. There exist several other similar performance tasks that aim to indirectly assess sleepiness (i.e., Oxford Sleep Resistance [148], Sustained Attention to Respond Task [149], PVT [59]). However, it is uncertain whether change of performance test would provide a better balance between feasibility in this particular context and the appropriate length to provide accurate data. There are several other ways to measure sleepiness – the most known are Multiple Sleep Latency Test and Maintenance of Wakefulness Test. However, these are costly, intrusive, and time consuming, and therefore challenging to conduct in field studies. Other ways to detect sleepiness include EEG signal interpretation (i.e., Alpha Attenuation Test [150]), ocular activity (i.e., Optalert [151]), pupillography, and simulation tests [41]. Albeit with their accompanied limitations, innovative use of the abovementioned tests could potentially enhance the quality of objectively assessed sleepiness acquired from field studies such as the present. In safety sensitive occupational groups and/or workers that provide services essential to society, implementation of exhaustive performance tasks may be both unpractical and unethical, prompting cost-benefit considerations. Innovative use of scales and performance testing in field studies could be one part of the solution to these challenges in future research. However, this imply that the tests can be completed with a minimum strain on the participants in order to avoid compromising the operational setting.

5.6.2 Design

The data collection length represents a strength of the overall design. However, the number on night missions were quite low in the NAA dataset. Research suggests that of all shift work types, night work is the most detrimental for the worker [68]. Thus, it would be interesting to follow each participant over several workweeks, exceeding one workweek per wave (the NAA workers). This would extend the amount of night missions per worker and thus our data on its effect on sleep.

5.6.3 Biases

Our data could be susceptible to social desirability bias, where the participants provide the answers they believe the researcher/society wants. However, inclusion of objective and subjective measures was done in order to compensate for such biases. Selection bias might also be present, where those who had sleep problems or were aware that they did not obtain sufficient amounts of sleep withstood from participation. However, as the response rate was high, one might assume that the majority perceived the study as an asset for their workplace safety.

Our findings may not be easily generalized to other populations due to the selection bias called the healthy (shift) worker effect. The healthy worker effect refers to a selection process resulting in a healthier workforce of shift workers compared to day workers. This selection process includes a pre-employment and post-employment phase. The pre-employment phase includes the individual’s appraisal of own capabilities, and a physician's medical examination and appraised health status. The post-employment phase includes the survivor effect, meaning that less healthy individuals are likely to self-select out of a shift work setting, regardless of the cause of health problems [152]. The pre-employment phase may likely be present in this context as the HEMS workers represent a highly selected group exceeding the normal shift work force. Given the nature of the occupation and the inherent risk of the work setting, the workers go through several examinations and tests prior to employment. The post-employment phase may also be present, for instance if workers who complete the pre-employment phase find that they are unsuitable for the extended shifts and long work hours that the NAA workers engage in. Although our findings may be challenging to apply to other shift work settings with different shift schedules and work characteristics, the findings are still considered valuable. In this project, we were interested in how this particular group of workers coped with their work setting regarding sleep and sleepiness, and comparable research is scarce. Thus, even if the healthy worker effect may be present, this work context requires a highly selected group as the setting do not fit the general population. In addition, the findings may be useful for occupational groups with similar shift schedules, work settings, and/or employee characteristics.

5.6.4 Field studies

Experimental shift work studies (i.e., simulated shift work studies) often imply a sample representative of the general work force. The results from such studies can provide knowledge about the general effects of shift work on humans and are less susceptible to biases such as healthy worker effect. However, field studies are often more ecological in nature, and enable examination of real-life settings with the specific shift workers as participants. By including the inherently selected occupational group, we possibly gain more access to complex situations that are challenging to study using other designs (i.e., experimental studies).

Disadvantages related to field studies include degree of control, generalizability, and sample size. The degree of control over the total amount of variables affecting the results is low, where there may exist confounding variables not captured by the instruments. Compared to epidemiological or cross-sectional studies which often have larger sample sizes (i.e., register-based studies), field studies usually have smaller samples sizes which limits the level of sophisticated analysis that can be conducted. However, the longitudinal design in our field study represents an asset by providing multiple data points per participant, per day, over 6 weeks.

5.7 Implications and future research

Our results indicated that the HEMS workers experienced low levels of sleepiness and obtained adequate amounts of sleep during their workweek. However, this is not an argument to render this occupational setting as harmless. Shortened sleep and increased sleepiness may pose substantial hazards on health, performance, and safety, for both the HEMS worker and their surroundings. Thus, functional Fatigue Risk Management Systems (FRMSs) are important to meet the challenges in these particular shift work settings. The hours-of-service regulations alone, comprised by the flight and duty time limitations in the HEMS, do not fully consider the complex interplay between sleep, circadian rhythm, and performance.

Garde and colleagues [153] made several recommendations regarding shift scheduling. They recommended maximum 3 consecutive night shifts, 11 h or more between the shifts, and a maximum shift duration of 9 h. Based on these proposals, it is evident that the shift schedule of the NAA and CFV workers are beyond the recommendations, but still seem to be a good fit for the work setting. This may be due to the protective function of the surrounding features, such as base facilities, shift structure demanding 24/7 (for the NAA workers) presence on the bases, recovery time between the workweeks, breaks between the missions, strict criteria for alarm initiation at the dispatch center, and the nature of missions implying shift of attention. The latter is supported by our findings, where number of missions was negatively associated with sleepiness while duration of missions was positively associated with sleepiness. Garde and colleagues [153] corroborate this by noting that other recommendations could apply for workers in remote workplaces with sleep promoting facilities. However, these are safety-critical work tasks and continuous development of FRMS is essential for the safety of these shift schedules in this occupational group.

By including elements of sleep and circadian rhythm in FRMSs of shift working HEMS, one could to a greater extent account for the complex interactions between these factors and performance in safety-sensitive settings. One examples of such elements could be proportional impact of duty hour limits along the biologic day, where duty hours during the biologic night could “weigh” more than corresponding hours during the day. Other elements include minimizing the number of consecutive nights the crews are operative and/or having extra crew checks related to sleep and sleepiness in periods where prolonged night work is unavoidable. The recommended maximum number of consecutive night shifts are three [11]. However, these results are largely based on populations with more definite rest structures during the corresponding daytime, whereas the HEMS workers risk getting missions or other interruptions during these hours. Thus, maybe even fewer consecutive nights of work should be considered in this particular occupational context. Other potentially beneficial elements are locally adjusted mitigating measures, based on the individual worker, base, and/or task. Individual adjustments could be based on individual sleep need (i.e., long- and short-sleepers) [35] or chronotype, where research indicates that evening types cope better with night work compared to morning types [154]. Base adjustments could include different measures between the urban and rural bases, where the mission profiles may differ in terms of number, duration, and type. Some bases may also benefit from seasonal adjustments based on coinciding behavioural change in the population. Task-based adjustments could include different modifications for missions and administrative duties or based on degree of monotony or length of the relevant tasks. Regular updates and education in shift work-specific sleep hygiene, in both management and crew, could increase knowledge about the complex processes and thus increase compliance with favourable sleep hygiene behaviour [155]. For instance, knowledge about ways to manage sleepiness, including strategic use of naps (i.e., prophylactic) and caffeine, as well as information about the latter’s properties (i.e., latency, half-time, caffeine crash) could be beneficial for shift working HEMS crews [156]. On that note, a recent study among shift working nurses found that proactive recovery programs had positive effects on fatigue [157]. Further, it could be beneficial with cultural evolvement on good sleep health by avoiding "can do"-attitude and debunking myths stating that sleepiness can be surmounted or that sleep can be stored. Visible support from the management could also affect compliance positively among the workers. The increase in use of personal health monitoring with smartwatches, trackers, and apps could be considered in a work setting where the worker keep track on sleep and sleepiness. Innovative products or designs could include objective sleep trackers (i.e., sleep radars), registration of body temperature or melatonin as an objective measure of the circadian rhythm and corresponding performance levels, or measures to detect microsleep. However, there are feasibility issues and ethical questions regarding privacy and storage that should be raised with implementation of such innovative trackers. In the future FRMS, a "sleepalyzer" that functions as a breathalyzer would be a desirable solution to sleep and sleepiness monitoring. Until that time, we will have to settle for increasing knowledge about sleep, sleepiness and circadian rhythms, and how this affects our ability to work at all hours. Simultaneously, we should continue to make adaptations to the individual settings, and further develop FRMSs and research in order to reduce the negative effects.

Several theoretical models have attempted to explain the relationship between shift work, sleep, and the potential consequences in short- and long-term [69, 70]. In their model, Kecklund and Axelsson [69] proposed several mechanisms by which shift work may lead to chronic disease and accidents, via the interaction of disturbed sleep, circadian disruption, and risk behaviours/psychological stress. They also incorporated shift work-related behaviour including altered light exposure, diet patterns, sleep patterns, and behaviours. The main elements proposed by Merkus and colleagues [70] included the interaction between work and non-work, and their associated physiological mechanisms. Underlying concepts within the work factor included working time duration, time-of-day, and recovery period. Further, the model postulated that the results of the interactions between work/non-work and physiological processes determined the short- and long-term health effects. Still, the existing explanatory models on shift work and sleep may not cover all aspects of all shift work arrangements. Because, despite the extensive amount of data that have documented the detrimental effects of shift work, the HEMS crews seemingly coped well regarding sleep and sleepiness. Although there are considerable uncertainties related to performance as measured by the reaction time tests, these also indicated short response time and high response accuracy during the workweek. Based on the thesis' findings, assumptions can be made regarding additional factors to supplement the existing theoretical models. This could make them more comprehensive and applicable to the variety of work settings and shift work schedules that exist, including the present HEMS work setting which consists of long work hours, on-call work, and with elements of night work.

One factor that might be lacking in the existing models is on-site living. On-site living during the workweek could serve as a sleep promoting factor by removing social and domestic obligations. In absence of missions or work tasks, the individual worker may prioritize sleep without competing tasks or obligations. However, being away from home and family may also have negative effects on the individual worker, depending on life situation. Another factor is base facilities (or workplace facilities). Good base facilities, especially related to each worker's sleeping areas could promote sleep, while poor facilities could curtail sleep. For instance, access to good-quality mattresses, duvets, pillows, and black-out curtains, and absence of noise in the sleeping area may positively affect the sleep. Additionally, access to private bathrooms could eliminate disturbances at night within the crew/group of workers, while exercise rooms allow for workouts which is beneficial for building up sleep pressure. Rest requirements during the work period, especially for groups who work long hours represent another factor. In the HEMS context, these are represented in the flight and duty time limitations which provide the workers with a minimum of rest requirements upon exceeding maximum amount of flight or duty time. However, they do not fully account for the interplay between sleep pressure and the circadian factor (i.e., time-of-day, duration of work). In the HEMS work setting, the alarm initiation criteria at the dispatch center represent another factor that may be relevant. Strict alarm criteria could pose as a protective feature for sleep and sleepiness, while the opposite could result in more missions or at least more mission alarms possibly affecting the sleep and sleepiness negatively. This could also be relevant for other on-call contexts. Mission characteristics could also be considered as a contributing factor. Because, the characteristics of the missions may affect the workers' sleep, where particularly demanding missions can influence the sleep and possibly make the workers vulnerable to the challenging aspects of the shift schedule. The selection of personnel represents the final factor, where the work setting results in a highly selected group that may be more robust in terms of performance when faced with periods of less sleep or higher levels of sleepiness. Additionally, the number of days between the workweeks could affect the workers. Sufficient amounts of recovery days would enable recuperation, whereas short rest period between shift could be detrimental. The latter factor is already included in the model by Merkus [70] but appraised as particularly important in the present occupational setting and therefore still deserves mentioning.

Several recommendations can be made regarding future research. Future research should focus on retrieving extensive amounts of data from the work setting in order to gain more nuanced knowledge about the sleep. Further, innovative use of instruments could maximize the amount of retrievable data without exhausting the participants or compromising the service. A quasi-experimental design with simulation of missions during a fictive workweek could enable inclusion of a more comprehensive battery of performance tests, which could provide further insight into how these schedules affect sleepiness and performance. Regarding the supplementary suggestions to the theoretical shift work models, future research would benefit from examining to what extent the suggested factors are present in comparable occupational settings. In such manner, the research field would gain more knowledge about how these factors interact and thus further develop the existing models.

5.8 Conclusion

This thesis examined how consecutive shifts and long work hours affected sleep and sleepiness among pilots and HCMs working in the HEMS. The research on this matter in HEMS is scarce, but nevertheless important. Thus, the novelty of our research represents an important contribution to the shift work field.

The results from Paper 1 suggested that the workers experienced low levels of sleepiness both during their workweek and their weeks off. The lowest sleepiness levels were interestingly found during the workweek. Over the course of a workweek, the highest (although low) sleepiness scores were reported on the first duty day. No change in the reaction time tests were evident over the workweek. The results in Paper 2 indicated that the workers went to bed later and spent less time in bed during the season with more missions (Wave 2) compared to the season with fewer missions (Wave 1). The workers' sleep period was more delayed and somewhat disturbed, during the workweek compared to the weeks off work. In Paper 3, the results from both pilot groups combined suggested a delay in the sleep period towards the workweek-end. Some differences between the two pilot groups were evident, where the NAA pilots had somewhat more disturbed sleep compared to the CFV pilots. However, the workers still obtained appropriate amounts of sleep during the entire data collection period with over 7 h and 6 h of sleep reported in Paper 2 and 3, respectively. For the latter, the NAA pilots obtained more sleep than the CFV pilots despite operating at all hours throughout the workweek.

Our findings suggested that the workers experienced low levels of sleepiness and obtained sufficient amounts of sleep during their workweek, despite working long hours over seven consecutive days. These results indicate that the current shift schedule is a good fit for this particular work setting including all its protective features (i.e., bases, facilities, on-site living) in terms of sleep and sleepiness. Nevertheless, it is important to underline that the conclusion is based on results derived from a group level. Thus, an ever-developing and advancing FRMS is still essential to protect the workers from the negative effects that shift work imply.

Moreover, in these safety-sensitive occupations, mitigating measures could also be beneficial. For instance, during particular periods of the day (i.e., window of circadian low) or in precarious situations where the crews may be vulnerable in terms of sleep, sleepiness and performance. Further research on these contexts is therefore also important to obtain updated information about these essential occupational groups.

Source of data

1. Hankins, D.G., *Air Medical Transport of Trauma Patients.* Prehosp Emerg Care, 2006. **10**(3): p. 324-327. doi: 10.1080/10903120600728748.
2. Monk, T.H. and S. Folkard, *Making shift work tolerable*. 1992, London: Taylor & Francis.
3. Wang, X.S., et al., *Shift work and chronic disease: the epidemiological evidence.* Occup Med (Lond), 2011. **61**(2): p. 78-89. doi: 10.1093/occmed/kqr001.
4. Eurofund, *Sixth European Working Condition Survey - Overview report (2017 update)*, 2017. Publications Office of the European Union, Luxembourg.
5. Statistics Norway, *Labour Force Survey*, Table 09730, Editor. 2020. Available from: https://www.ssb.no/statbank/table/09730/
6. European Parliament and Council of the European Union, *Directive 2003/88/EC of the European Parliament and of the Council of 4 November 2003 concerning certain aspects of the organisation of working time*, in *L299*. 2003, Off. J. Eur. Union, p. 9-11. [cited 2022 12th of August]; Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32003L0088
7. Working Environment Act, *Act relating to working environment, working hours and employment protection, etc* (LOV-2005-06-17-62). 2006.
8. Stevens, R.G., et al., *Considerations of circadian impact for defining 'shift work' in cancer studies: IARC Working Group Report.* Occup Environ Med, 2011. **68**(2): p. 154-162. doi: 10.1136/oem.2009.053512.
9. Sallinen, M. and G. Kecklund, *Shift work, sleep, and sleepiness—differences between shift schedules and systems.* Scand J Work Environ Health, 2010: p. 121-133.
10. Drake, C.L. and K.P. Wright, *Shift work, Shift-Work Disorder, and Jet Lag*, in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 784-798.

11. Kecklund, G., M. Sallinen, and J. Axelsson, *Optimizing Shift Scheduling* in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 742-749.e4.
12. Siegel, J.M., *Sleep viewed as a state of adaptive inactivity.* Nat Rev Neurosci, 2009. **10**(10): p. 747.
13. Walker, M., *Why We Sleep: unlocking the power of sleep and dreams* 2017, New York, NY: Scribner.
14. Cirelli, C. and G. Tononi, *The Sleeping Brain.* Cerebrum, 2017. **2017**.
15. Perogamvros, L. and S. Schwartz, *Sleep and Emotional Functions*, in *Sleep, Neuronal Plasticity and Brain Function*, Meerlo P., Benca R. M., and Abel T., Editors. 2013, Springer.
16. Morselli, L.L., A. Guyon, and K. Spiegel, *Sleep and metabolic function.* Pflugers Arch - Eur J Physiol, 2012. **463**(1): p. 139-160. doi: 10.1007/s00424-011-1053-z.
17. Xie, L., et al., *Sleep Drives Metabolite Clearance from the Adult Brain.* Science, 2013. **342**(6156): p. 373-377. doi: 10.1126/science.1241224.
18. Rosenwasser, A.M. and F.W. Turek, *Neurobiology of circadian rhythm regulation.* Sleep Med Clin, 2015. **10**(4): p. 403-412. doi: 10.1016/j.jsmc.2015.08.003.
19. Pallesen, S. and B. Bjorvatn, *Døgnrytmeforstyrrelser.* Tids Nor L, 2009. **129**(18): p. 1884-7.
20. Czeisler, C.A., et al., *Stability, Precision, and Near-24-Hour Period of the Human Circadian Pacemaker.* Science, 1999. **284**(5423): p. 2177-2181. doi: 10.1126/science.284.5423.2177.
21. Dijk, D.-J. and S.N. Archer, *Light, sleep, and circadian rhythms: together again.* PLoS biology, 2009. **7**(6): p. e1000145. doi: 10.1371/journal.pbio.1000145.
22. Skene, D.J. and J. Arendt, *Human circadian rhythms: physiological and therapeutic relevance of light and melatonin.* Ann Clin Biochem, 2006. **43**(5): p. 344-353. doi: 10.1258/000456306778520142.

23. Dijk, D.-J. and H.-P. Landolt, *Sleep physiology, circadian rhythms, waking performance and the development of sleep-wake therapeutics*, in *Sleep-wake neurobiology and pharmacology*, D.-J. Dijk and H.-P. Landolt, Editors. 2019, Springer. p. 441-481.
24. Zhdanova, I.V., H.J. Lynch, and R.J. Wurtman, *Melatonin: a sleep-promoting hormone.* Sleep, 1997. **20**(10): p. 899-907. doi: 10.1093/sleep/20.10.899.
25. Gaberhart, R.J. and H.P.A. Van Dongen, *Circadian Rhythms in Sleepiness, Alertness, and Performance*, in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 388-395.
26. Iber, C., et al., *The AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications*. 2007, Westchester, IL: American Academy of Sleep Medicine.
27. Chokroverty, S., *Overview of Normal Sleep*, in *Sleep Disorders Medicine*. 2017, Springer New York: New York, NY. p. 5-27.
28. Carskadon, M.A. and W.C. Dement, *Normal Human Sleep: An Overview*, in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 15-24.
29. Borbély, A.A., *A two process model of sleep regulation.* Hum Neurobiol, 1982. **1**(3): p. 195-204.
30. Borbély, A.A., et al., *The two-process model of sleep regulation: a reappraisal.* J Sleep Res, 2016: p. 131-143. doi: 10.1111/jsr.12371.
31. Folkard, S. and T. Åkerstedt, *Towards a model for the prediction of alertness and/or fatigue on different sleep/wake schedules*, in *Contemporary advances in shiftwork research. Krakow: Medical Academy*, A. Oginski, J. Pokorski, and J. Rutenfranz, Editors. 1987, Medical Academy: Krakow. p. 231-40.
32. Ohayon, M.M., et al., *Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: Developing normative sleep values across the human lifespan.* Sleep, 2004. **27**(7): p. 1255-1273. doi: 10.1093/sleep/27.7.1255.

33. National Sleep Foundation. *2005 Sleep in America Poll - Health and Safety*. 2005. [cited 2022 4th of March]; Available from: https://www.thensf.org/wp-content/uploads/2021/03/2005_summary_of_findings.pdf.

34. Hirshkowitz, M., et al., *National Sleep Foundation's sleep time duration recommendations: methodology and results summary.* Sleep Health, 2015. **1**(1): p. 40-43. doi: 10.1016/j.sleh.2014.12.010.

35. Aeschbach, D., et al., *A Longer Biological Night in Long Sleepers Than in Short Sleepers.* J Clin Endocrinol Metab, 2003. **88**(1): p. 26-30. doi: 10.1210/jc.2002-020827.

36. Roenneberg, T., et al., *Social Jetlag and Obesity.* Curr Biol, 2012. **22**(10): p. 939-943. doi: 10.1016/j.cub.2012.03.038.

37. Costa, G., *Sleep deprivation due to shift work.* Handb Clin Neurol, 2015. **131**: p. 437-446. doi: 10.1016/B978-0-444-62627-1.00023-8.

38. Stone, K.L. and S. Ancoli-Israel, *Actigraphy*, in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 1671-1678.

39. Carney, C.E., et al., *The Consensus Sleep Diary: Standardizing Prospective Sleep Self-Monitoring.* Sleep, 2012. **35**(2): p. 287-302. doi: 10.5665/sleep.1642.

40. Toften, S., et al., *Validation of sleep stage classification using non-contact radar technology and machine learning (Somnofy®).* Sleep Med, 2020. **75**: p. 54-61. doi: 10.1016/j.sleep.2020.02.022.

41. Baiardi, S. and S. Mondini, *Inside the clinical evaluation of sleepiness: subjective and objective tools.* Sleep Breath, 2020. **24**(1): p. 369-377. doi: 10.1007/s11325-019-01866-8.

42. Carskadon, M.A. and W.C. Dement, *Daytime sleepiness: Quantification of a behavioral state.* Neurosci Biobehav Rev, 1987. **11**(3): p. 307-317. doi: 10.1016/S0149-7634(87)80016-7.

43. Pallesen, S., et al., *Prevalence and risk factors of subjective sleepiness in the general adult population.* Sleep, 2007. **30**(5): p. 619. doi: 10.1093/sleep/30.5.619.

44. Carskadon, M.A. and W.C. Dement, *Nocturnal determinants of daytime sleepiness.* Sleep, 1982. **5**(suppl_2): p. S73-S81.

45. Carskadon, M.A., *Guidelines for the multiple sleep latency test (MSLT): a standard measure of sleepiness.* Sleep, 1986. **9**(4): p. 519-524. doi: 10.1093/sleep/9.4.519.

46. Pelayo, R. and W.C. Dement, *History of Sleep Physiology and Medicine*, in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 3-14.

47. Johns, M.W., *A new method for measuring daytime sleepiness: the Epworth sleepiness scale.* sleep, 1991. **14**(6): p. 540-545. doi: 10.1093/sleep/14.6.540.

48. Zwyghuizen-Doorenbos, A., et al., *Test-retest reliability of the MSLT.* Sleep, 1988. **11**(6): p. 562-565. doi: 10.1093/sleep/11.6.562.

49. Bliwise, D.L., et al., *MSLT-defined sleepiness and neuropsychological test performance do not correlate in the elderly.* Neurobiol Aging, 1991. **12**(5): p. 463-468. doi: 10.1016/0197-4580(91)90074-T.

50. Shen, J., J. Barbera, and C.M. Shapiro, *Distinguishing sleepiness and fatigue: focus on definition and measurement.* Sleep Med Rev, 2006. **10**(1): p. 63-76. doi: 10.1016/j.smrv.2005.05.004.

51. Van Dongen, H.P.A., et al., *The Cumulative Cost of Additional Wakefulness: Dose-Response Effects on Neurobehavioral Functions and Sleep Physiology From Chronic Sleep Restriction and Total Sleep Deprivation.* Sleep, 2003: p. 117-126. doi: 10.1093/sleep/26.2.117.

52. Åkerstedt, T. and M. Gillberg, *Subjective and Objective Sleepiness in the Active Individual.* Int J Neurosci, 1990. **52**(1-2): p. 29-37. doi: 10.3109/00207459008994241.

53. Kaida, K., et al., *Validation of the Karolinska sleepiness scale against performance and EEG variables.* Clin Neurophysiol, 2006. **117**(7): p. 1574-1581. doi: 10.1016/j.clinph.2006.03.011.
54. Åkerstedt, T., D. Hallvig, and G. Kecklund, *Normative data on the diurnal pattern of the Karolinska Sleepiness Scale ratings and its relation to age, sex, work, stress, sleep quality and sickness absence/illness in a large sample of daytime workers.* J Sleep Res, 2017. **26**(5): p. 559-566. doi: 10.1111/jsr.12528.
55. Eberhart, R., X. Hu, and B. Foresman, *Dangers of sleepiness and inattention while driving.* JOM, 2000. **100**(s8): p. 9-14. doi: 10.7556/jaoa.2000.20030.
56. Åkerstedt, T., G. Kecklund, and A. Knutsson, *Manifest sleepiness and the spectral content of the EEG during shift work.* Sleep, 1991. **14**(3): p. 221-225. doi: 10.1093/sleep/14.3.221.
57. Roehrs, T., et al., *Daytime Sleepiness and Alertness*, in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 39-48.
58. Bjorvatn, B., et al., *Self-reported sleep and health among Norwegian hospital nurses in intensive care units.* Nurs Crit Care, 2012. **17**(4): p. 180-188. doi: 10.1111/j.1478-5153.2012.00504.x.
59. Dinges, D.F., et al., *Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night.* Sleep, 1997. **20**(4): p. 267-277. doi: 10.1093/sleep/20.4.267.
60. Åkerstedt, T. and K.P. Wright, *Sleep loss and fatigue in shift work and shift work disorder.* Sleep Med Clin, 2009. **4**(2): p. 257-271. doi: 10.1016/j.jsmc.2009.03.001.
61. Pallesen, S. and B. Bjorvatn, *Workload and Fatigue*, in *Space Safety and Human Performance*, T. Sgobba, et al., Editors. 2017, Elsevier.

62. Rosekind, M.R., et al., *Crew factors in flight operations IX: effects of planned cockpit rest on crew performance and alertness in long-haul operations*. 1994, NASA: Unites States.

63. Bendak, S. and H.S.J. Rashid, *in aviation: A systematic review of the literature.* Int J Ind Ergon, 2020. **76**: p. 102928. doi: 10.1016/j.ergon.2020.102928.

64. Lim, J. and D.F. Dinges, *Sleep Deprivation and Vigilant Attention.* Ann N Y Acad Sci, 2008. **1129**(1): p. 305-322. doi: 10.1196/annals.1417.002.

65. Mollicone, D.J., et al., *Time of day effects on neurobehavioral performance during chronic sleep restriction.* ASEM, 2010. **81**(8): p. 735-744. doi: 10.3357/ASEM.2756.2010.

66. Killgore, W.D. and M. Weber, *Sleep deprivation and cognitive performance*, in *Sleep deprivation and disease*, M.T. Bianchi, Editor. 2014, Springer: New York, NY. p. 209-229.

67. Dinges, D.F. and J.W. Powell, *Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations.* Behav Res Meth Instrum Comput, 1985. **17**(6): p. 652-655.

68. Smith, M.R. and C.I. Eastman, *Shift work: health, performance and safety problems, traditional countermeasures, and innovative management strategies to reduce circadian misalignment.* Nat Sci Sleep, 2012. **4**: p. 111-132. doi: 10.2147/NSS.S10372.

69. Kecklund, G. and J. Axelsson, *Health consequences of shift work and insufficient sleep.* Bmj, 2016. **355**: p. i5210. doi: 10.1136/bmj.i5210.

70. Merkus, S.L., et al., *Nonstandard working schedules and health: the systematic search for a comprehensive model.* BMC Public Health, 2015. **15**(1): p. 1-15. doi: 10.1186/s12889-015-2407-9.

71. Åkerstedt, T., *Shift work and disturbed sleep/wakefulness.* Occup Med, 2003. **53**(2): p. 89-94. doi: 10.1093/occmed/kqg046.

72. Øyane, N.M., et al., *Associations between night work and anxiety, depression, insomnia, sleepiness and fatigue in a sample of Norwegian*

nurses. PloS one, 2013. **8**(8): p. e70228. doi: 10.1371/journal.pone.0070228.

73. American Academy of Sleep Medicine, *International Classification of Sleep Disorders*. 3rd ed. 2014, Darien, IL: American Academy of Sleep Medicine.
74. Pallesen, S., et al., *Prevalence of Shift Work Disorder: A Systematic Review and Meta-Analysis.* Front Psychol, 2021. **12**: p. 638252-638252. doi: 10.3389/fpsyg.2021.638252.
75. Waage, S., et al., *Shift Work Disorder Among Oil Rig Workers in the North Sea.* Sleep, 2009. **32**(4): p. 558-565. doi: 10.1093/sleep/32.4.558.
76. Åkerstedt, T., G. Kecklund, and J. Selén, *Early Morning Work-Prevalence and Relation to Sleep Wake Problems: A National Representative Survey.* Chronobiol Int, 2010. **27**(5): p. 975-986. doi: 10.3109/07420528.2010.489001.
77. Viitasalo, K., et al., *Effects of Shift Rotation and the Flexibility of a Shift System on Daytime Alertness and Cardiovascular Risk Factors.* Scand J Work Environ Health, 2008. **34**(3): p. 198-205. doi: 10.5271/sjweh.1228.
78. Costa, G., *Shift Work and Health: Current Problems and Preventive Actions.* Saf Health Work, 2010. **1**(2): p. 112-123. doi: 10.5491/SHAW.2010.1.2.112.
79. Caruso, C.C., *Negative impacts of shiftwork and long work hours.* Rehabil Nurs, 2014. **39**(1): p. 16-25. doi: 10.1002/rnj.107
80. Torsvall, L. and T. Åkerstedt, *Disturbed sleep while being on-call: an EEG study of ships' engineers.* Sleep, 1988. **11**(1): p. 35-38. doi: 10.1093/sleep/11.1.35.
81. Ziebertz, C.M., et al., *The effect on sleep of being on-call: an experimental field study.* J Sleep Res, 2017. **26**(6): p. 809-815. doi: 10.1111/jsr.12519.
82. Dru, M., et al., *Overnight duty impairs behaviour, awake activity and sleep in medical doctors.* Eur J Emerg Med, 2007. **14**(4): p. 199-203. doi: 10.1097/MEJ.0b013e3280bef7b0.

83. Arora, V.M., et al., *Association of workload of on-call medical interns with on-call sleep duration, shift duration, and participation in educational activities.* JAMA, 2008. **300**(10): p. 1146-1153. doi: 10.1001/jama.300.10.1146.

84. Ferguson, S.A., et al., *On-call work: To sleep or not to sleep? It depends.* Chronobiol Int, 2016. **33**(6): p. 678-684. doi: 10.3109/07420528.2016.1167714.

85. Saksvik, I.B., et al., *Individual differences in tolerance to shift work – A systematic review.* Sleep Med Rev, 2011. **15**(4): p. 221-235. doi: 10.1016/j.smrv.2010.07.002.

86. Viola, A.U., et al., *PER3 Polymorphism Predicts Sleep Structure and Waking Performance.* Curr Biol, 2007. **17**(7): p. 613-618. doi: 10.1016/j.cub.2007.01.073.

87. Drake, C.L., et al., *Shift work sleep disorder: Prevalence and consequences beyond that of symptomatic day workers.* Sleep, 2004. **27**(8): p. 1453-1462. doi: 10.1093/sleep/27.8.1453.

88. Wickwire, E.M., et al., *Shift work and shift work sleep disorder: clinical and organizational perspectives.* Chest, 2017. **151**(5): p. 1156-1172. doi: 10.1016/j.chest.2016.12.007.

89. Durmer, J.S. and D.F. Dinges, *Neurocognitive consequences of sleep deprivation.* Semin Neurol, 2005. **25**(01): p. 117-129. doi: 10.1055/s-2005-867080.

90. Cajochen, C., S.L. Chellappa, and C. Schmidt, *Circadian and light effects on human sleepiness–alertness*, in *Sleepiness and human impact assessment*, S. Garbarino, L. Nobili, and G. Costa, Editors. 2014, Springer: Italy. p. 9-22.

91. Dall'Ora, C., et al., *Characteristics of shift work and their impact on employee performance and wellbeing: A literature review.* Int J Nurs Stud, 2016. **57**: p. 12-27. doi: 10.1016/j.ijnurstu.2016.01.007.

92. Wagstaff, A. and J. Lie, *Shift and night work and long working hours - a systematic review of safety implications.* Scand J Work Environ Health, 2011. **37**: p. 173-185. doi: 10.5271/sjweh.3146.

93. Matre, D., et al., *Safety incidents associated with extended working hours. A systematic review and meta-analysis.* Scand J Work Environ Health, 2021. **47**(6): p. 415. doi: 10.5271/sjweh.3958.

94. Folkard, S. and P. Tucker, *Shift work, safety and productivity.* Occup Med, 2003. **53**(2): p. 95-101. doi: 10.1093/occmed/kqg047.

95. Larsen, A.D., et al., *Night work, long work weeks, and risk of accidental injuries. A register-based study.* Scand J Work Environ Health, 2017: p. 578-586. doi: 10.5271/sjweh.3668.

96. Weaver, M.D., et al., *An observational study of shift length, crew familiarity, and occupational injury and illness in emergency medical services workers.* Occup Environ Med, 2015. **72**(11): p. 798-804. doi: 10.1136/oemed-2015-102966.

97. Vedaa, Ø., et al., *A longitudinal study on the association between quick returns and occupational accidents.* Scand J Work Environ Health, 2020. **46**(6): p. 645. doi: 10.5271/sjweh.3906.

98. Bioulac, S., et al., *Risk of motor vehicle accidents related to sleepiness at the wheel: a systematic review and meta-analysis.* Sleep, 2017. **40**(10). doi: 10.1093/sleep/zsx134.

99. Barr, J. and S. Montgomery, *Helicopter medical evacuation in the Korean War: Did it matter?* J Trauma Acute Care Surg, 2019. **87**(1S): p. S10-S13. doi: 10.1097/TA.0000000000002218.

100. Norwegian Official Report 1998:8, *The Air Ambulance Service in Norway*. 1998, Ministry of Health and Care Services.

101. Neel, S., *Army Aeromedical Evacuation Procedures in Vietnam*. JAMA, 1968. **204**(4): p. 309-313.

102. Radstaak, M., et al., *Work Stressors, Perseverative Cognition and Objective Sleep Quality : A Longitudinal Study among Dutch Helicopter*

Emergency Medical Service (HEMS) Pilots. J Occup Health, 2014. **56**(6): p. 469-477. doi: 10.1539/joh.14-0118-OA.

103. Sallinen, M., et al., *Working hours, sleep and alertness in HEMS personnel in Finland*. 2018, Finnish Institute of Occupational Health Finland.

104. Zakariassen, E., et al., *Causes and Management of Sleepiness Among Pilots in a Norwegian and an Austrian Air Ambulance Service—A Comparative Study.* Air Med J, 2019. **38**(1): p. 25-29. doi: 10.1016/j.amj.2018.11.002.

105. Frakes, M. and J. Kelly, *Sleep Debt and Outside Employment Patterns in Helicopter Air Medical Staff Working 24-Hour Shifts.* Air Med J, 2007. **26**(1): p. 45-49. doi: 10.1016/j.amj.2006.05.003.

106. Allen, T.L., et al., *Intubation Successrate by Air Ambulance Personnel During 12- Versus 24-Hour Shifts: Does Fatigue Make a Difference?* Prehosp Emerg Care, 2001. **5**(4): p. 340-343. doi: 10.1080/10903120190939481.

107. Federal Aviation Administration, *Basics of Aviation Fatigue* (report no: 120-100). 2010. [cited 2022 9th of August]; Available from: https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/244560

108. Brown, D.B. and J. Masor, *Legal Aspects of Fatigue- and Safety-Sensitive Professions*, in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 666-669.

109. EASA, *Data Collection and Comparative Assessment of Existing National FTL Provisions for EMS* (report no: D1 No:3). 2012.

110. Gillberg, M., G. Kecklund, and T. Åkerstedt, *Relations between performance and subjective ratings of sleepiness during a night awake.* Sleep, 1994. **17**(3): p. 236-241. doi: 10.1093/sleep/17.3.236.

111. Morin, C.M., *Insomnia : psychological assessment and management*. Treatment manual for practitioners. 1993, New York, NY: Guilford Press.

112. Gundersen, H., et al., *Visual attention in patients with intracranial arachnoid cysts.* J Neurol, 2007. **254**(1): p. 60-66. doi: 10.1007/s00415-006-0280-2.

113. Posner, M.I. and J. Driver, *The neurobiology of selective attention.* Curr Opin Neurobiol, 1992. **2**(2): p. 165-169. doi: 10.1016/0959-4388(92)90006-7.

114. CamNtech Ltd, *The Actiwatch use manual version 7.2.* 2008, Cambridge, UK: CamNtech Ltd.

115. Chow, C.M., et al., *Defining the rest interval associated with the main sleep period in actigraph scoring.* Nat Sci Sleep, 2016. **8**: p. 321. doi: 10.2147/NSS.S114969.

116. Dahlgren, A., et al., *Quick returns and night work as predictors of sleep quality, fatigue, work–family balance and satisfaction with work hours.* Chronobiol Int, 2016. **33**(6): p. 759-767. doi: 10.3109/07420528.2016.1167725.

117. Vedaa, Ø., et al., *Systematic review of the relationship between quick returns in rotating shift work and health-related outcomes.* Ergonomics, 2016. **59**(1): p. 1-14. doi: 10.1080/00140139.2015.1052020.

118. Goffeng, E.M., et al., *Risk of fatigue among airline crew during 4 consecutive days of flight duty.* Aerosp Med Hum Perform, 2019. **90**(5): p. 466-474. doi: 10.3357/AMHP.5236.2019.

119. Bjorvatn, B., et al., *Subjective and objective measures of adaptation and readaptation to night work on an oil rig in the North Sea.* Sleep, 2006. **29**(6): p. 821-829. doi: 10.1093/sleep/29.6.821.

120. Waage, S., et al., *Subjective and objective sleepiness among oil rig workers during three different shift schedules.* Sleep medicine, 2012. **13**(1): p. 64-72. doi: 10.1016/j.sleep.2011.04.009.

121. Forberg, K., et al., *Subjective and objective sleep and sleepiness among tunnel workers in an extreme and isolated environment: 10-h shifts, 21-day working period, at 78 degrees north.* Sleep Med, 2010. **11**(2): p. 185-190. doi: 10.1016/j.sleep.2009.07.015.

122. European Cockpit Association, *Pilot Fatige Barometer*. 2012. [cited 2022 9th of August]; Available from:

https://www.eurocockpit.be/sites/default/files/2017-04/Barometer%20on%20pilot%20fatigue%2C%20ECA%202012.pdf

123. Thomas, F., et al., *Sleep and cognitive performance of flight nurses after 12-hour evening versus 18-hour shifts.* Air Med J, 2006. **25**(5): p. 216-225. doi: 10.1016/j.amj.2006.06.005.

124. Stepanski, E., et al., *Experimental sleep fragmentation in normal subjects.* Int J Neurosci, 1987. **33**(3-4): p. 207-214. doi: 10.3109/00207458708987405.

125. Jones, K. and Y. Harrison, *Frontal lobe function, sleep loss and fragmented sleep.* Sleep Med Rev, 2001. **5**(6): p. 463-475. doi: 10.1053/smrv.2001.0203.

126. Stepanski, E.J., *The effect of sleep fragmentation on daytime function.* Sleep, 2002. **25**(3): p. 268-276.

127. Bonnet, M.H. and D.L. Arand, *Clinical effects of sleep fragmentation versus sleep deprivation.* Sleep Med Rev, 2003. **7**(4): p. 297-310. doi: 10.1053/smrv.2001.0245.

128. Gupta, C.C., et al., *On-call work and sleep: The importance of switching on during a callout and switching off after a call.* Ind health, 2022. **60**(2): p. 91-96. doi: 10.2486/indhealth.2021-0124.

129. Vincent, G.E., et al., *What factors influence the sleep of on-call workers?* Behav Sleep Med, 2021. **19**(2): p. 255-272. doi: 10.1080/15402002.2020.1733575.

130. Vila, B., C. Samuels, and N.J. Wesensten, *Sleep Problems in First Responders and in Deployed Military Personnel*, in *Principles and Practice of Sleep Medicine*, M. Kryger, T. Roth, and W.C. Dement, Editors. 2017, Elsevier. p. 726-735.

131. Lo, J.C., et al., *Cognitive performance, sleepiness, and mood in partially sleep deprived adolescents: the need for sleep study.* Sleep, 2016. **39**(3): p. 687-698. doi: 10.5665/sleep.5552.

132. Roach, G.D., D. Dawson, and N. Lamond, *Can a shorter psychomotor vigilance task be usedas a reasonable substitute for the ten-minute*

psychomotor vigilance task? Chronobiol Int, 2006. **23**(6): p. 1379-1387. doi: 10.1080/07420520601067931.

133. Horne, J.A. and S.D. Baulk, *Awareness of sleepiness when driving.* Psychophysiology, 2004. **41**(1): p. 161-165. doi: 10.1046/j.1469-8986.2003.00130.x.

134. Mostofsky, S.H. and D.J. Simmonds, *Response inhibition and response selection: two sides of the same coin.* J Cogn Neurosci, 2008. **20**(5): p. 751-761. doi: 10.1162/jocn.2008.20500.

135. Drummond, S.P., M.P. Paulus, and S.F. Tapert, *Effects of two nights sleep deprivation and two nights recovery sleep on response inhibition.* J Sleep Res, 2006. **15**(3): p. 261-265. doi: 10.1111/j.1365-2869.2006.00535.x.

136. Curtis, A.F., et al., *Discrepancies in sleep diary and actigraphy assessments in adults with fibromyalgia: Associations with opioid dose and age.* J Sleep Res, 2019. **28**(5): p. e12746. doi: 10.1111/jsr.12746.

137. Matthews, K.A., et al., *Similarities and differences in estimates of sleep duration by polysomnography, actigraphy, diary, and self-reported habitual sleep in a community sample.* Sleep Health, 2018. **4**(1): p. 96-103. doi: 10.1016/j.sleh.2017.10.011.

138. Baek, J., K. Han, and S. Choi-Kwon, *Sleep diary-and actigraphy-derived sleep parameters of 8-hour fast-rotating shift work nurses: A prospective descriptive study.* Int J Nurs Stud, 2020. **112**: p. 103719. doi: 10.1016/j.ijnurstu.2020.103719.

139. Bjorvatn, B. *Normal Sleep*. 2021. [cited 2022 16th of August]; Available from: https://helse-bergen.no/nasjonal-kompetansetjeneste-for-sovnsykdommer-sovno/normal-sovn.

140. Bjorvatn, B., et al., *Insomni.* Tids Nor L, 2009(17). doi: 10.4045/tidsskr.08.0379.

141. Rezaie, L., et al., *Paradoxical insomnia and subjective–objective sleep discrepancy: A review.* Sleep Med Rev, 2018. **40**: p. 196-202. doi: 10.1016/j.smrv.2018.01.002.

142. Sadeh, A., *The role and validity of actigraphy in sleep medicine: an update.* Sleep Med Rev, 2011. **15**(4): p. 259-267. doi: 10.1016/j.smrv.2010.10.001.

143. De Alcantara Borba, D., et al., *How many days are needed for a reliable assessment by the Sleep Diary?* Sleep Science, 2019. **13**(1): p. 49. doi: 10.5935/1984-0063.20190131.

144. Morgenthaler, T., et al., *Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders: an update for 2007.* Sleep, 2007. **30**(4): p. 519-529. doi: 10.1093/sleep/30.4.519.

145. Sivertsen, B., et al., *A comparison of actigraphy and polysomnography in older adults treated for chronic primary insomnia.* Sleep, 2006. **29**(10): p. 1353-1358. doi: 10.1093/sleep/29.10.1353.

146. Meltzer, L.J., et al., *Direct comparison of two new actigraphs and polysomnography in children and adolescents.* Sleep, 2012. **35**(1): p. 159-166. doi: 10.5665/sleep.1608.

147. Hong, H., et al., *Microwave sensing and sleep: Noncontact sleep-monitoring technology with microwave biomedical radar.* IEEE Microw, 2019. **20**(8): p. 18-29. doi: 10.1109/MMM.2019.2915469.

148. Bennett, L., J. Stradling, and R. Davies, *A behavioural test to assess daytime sleepiness in obstructive sleep apnoea.* J Sleep Res, 1997. **6**(2): p. 142-145. doi: 10.1046/j.1365-2869.1997.00039.x.

149. Fronczek, R., et al., *Focusing on vigilance instead of sleepiness in the assessment of narcolepsy: high sensitivity of the Sustained Attention to Response Task (SART).* Sleep, 2006. **29**(2): p. 187-191. doi: 10.1093/sleep/29.2.187.

150. Stampi, C., P. Stone, and A. Michimori, *A new quantitative method for assessing sleepiness: the Alpha Attenuation Test.* Work & Stress, 1995. **9**(2-3): p. 368-376. doi: 10.1080/02678379508256574.

151. Corbett, M., *Science & Technology Watch: A Drowsiness Detection System for Pilots: Optalert®.* ASEM, 2009. **80**(2): p. 149-149. doi: 10.3357/ASEM.21001.2009

152. Knutsson, A., *Methodological aspects of shift-work research.* Chronobiol Int, 2004. **21**(6): p. 1037-1047. doi: 10.1081/CBI-200038525.
153. Garde, A.H., et al., *How to schedule night shift work in order to reduce health and safety risks.* Scand J Work Environ Health, 2020. **46**(6): p. 557. doi: 10.5271/sjweh.3920.
154. Vetter, C., et al., *Aligning work and circadian time in shift workers improves sleep and reduces circadian disruption.* Curr Biol, 2015. **25**(7): p. 907-911. doi: 10.1016/j.cub.2015.01.064.
155. Chen, P.-H., H.-Y. Kuo, and K.-H. Chueh, *Sleep hygiene education: efficacy on sleep quality in working women.* J Nurs Res, 2010. **18**(4): p. 283-289. doi: 10.1097/JNR.0b013e3181fbe3fd.
156. Irish, L.A., et al., *The role of sleep hygiene in promoting public health: A review of empirical evidence.* Sleep Med Rev, 2015. **22**: p. 23-36. doi: 10.1016/j.smrv.2014.10.001.
157. Dahlgren, A., et al., *Randomised control trial of a proactive intervention supporting recovery in relation to stress and irregular work hours: effects on sleep, burn-out, fatigue and somatic symptoms.* Occup Environ Med, 2022. doi: 10.1136/oemed-2021-107789.

International Archives of Occupational and Environmental Health (2019) 92:1121–1130
https://doi.org/10.1007/s00420-019-01449-w

ORIGINAL ARTICLE

Sleepiness among personnel in the Norwegian Air Ambulance Service

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Received: 20 February 2019 / Accepted: 4 June 2019 / Published online: 10 June 2019

Abstract

Purpose To examine the effects of shift work and extended working hours on sleepiness among pilots and Helicopter Emergency Medical Service (HEMS) crew members in the Norwegian Air Ambulance.

Methods This field study investigated sleepiness during 3 consecutive weeks: the week before work, the work week, and the week after work. The pilots and HEMS crew members ($N=50$) kept a wake diary during all 3 weeks and completed reaction time tests during the work week.

Results The overall sleepiness scores were low during all 3 weeks. When comparing the 3 weeks, the lowest sleepiness levels were found for the work week. There was a small difference across work days, in which subjective sleepiness scores were highest the first duty day. No change in the reaction time tests was evident during the work week. The crew members reported being most sleepy at midnight, compared to all the other timepoints over the course of a duty day. Regarding workload and total work time, having larger workload was associated with lower sleepiness scores, while having higher total work time was associated with higher sleepiness score, both compared to the medium category.

Conclusions The findings indicate that the work schedules and setting for this distinct occupational group do not seem to negatively affect the sleepiness levels.

Keywords Sleepiness · Shift work · Air ambulance · Pilots · HEMS crew members

Introduction

To maintain around the clock operations, a large portion of the workforce must be organized in shift work and often works extended hours. Shift work can generally be denoted as work outside normal daytime, and may include work during evening, night, and weekend (National Sleep Foundation 2018). Shift work, including night shift, implies activity and light exposure at a time when inactivity and rest are natural (Akerstedt and Wright 2009). Work during the natural night often influence sleep and functioning and may result in shortened sleep and/or increased sleepiness (Swanson et al. 2011). Studies generally suggest a reduction of sleep duration by approximately 3 h following night shifts (Sallinen and Kecklund 2010), and severe sleepiness has been found during night shift, as this coincides with the nadir for the core body temperature (Härmä et al. 2002; Akerstedt and Wright 2009). Night work is, therefore, associated with impaired performance and occupational accidents (Härmä and Kecklund 2010; Wagstaff and Lie 2011). In addition, working irregular shifts poses a risk for increased sleepiness and sleep debt, indicating an elevated need for recovery (Härmä et al. 2018). Extended working hours have been defined as work exceeding 48 h a week (Harrington 2001). The literature regarding the effect of such working hours on sleep and sleepiness is inconsistent. Some studies suggest that long working hours are associated with increased sleepiness and shortened sleep (Sallinen and Kecklund 2010; Swanson et al. 2011), while other studies conclude that workers adapt quite well (Bjorvatn et al. 2006; Forberg

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et al. 2010). A review article concluded that extended working hours increased the risk of excessive sleepiness, which further could have implications for performance on the job and injuries (Caruso 2014). Shift work and extended work hours are common in aviation. Many flight operations include long-haul flights and crossing of several time zones. However, these work conditions are quite different from those in the Helicopter Emergency Medical Services (HEMS) characterized by on-demand medical service implying low predictability of workload and work hours. The work schedule and conditions of HEMS crews vary a great deal, both between countries and agencies. Some work 12-, 24-, or 48-h shifts, while others work 7 consecutive days. Furthermore, some live on the base, while others commute home every day when off work (Radstaak et al. 2014; Sallinen et al. 2018). These differences complicate generalization of findings across various operations, schedules, and conditions. In Norway, HEMS crews work 24-h shifts over 7 consecutive days to provide around the clock coverage and operation. However, little is known about the effects this type of shift schedules and these work characteristics have on sleepiness. Sleepiness is established as a risk factor in aviation, and evidence suggests that sleepiness is associated with flying errors and accidents (Goode 2003; Previc et al. 2009). A common distinction is drawn between subjective and objective sleepiness. Objective measures of sleepiness may include measures of sleep tendency (i.e., the Multiple Sleep Latency Test), reduced activation (i.e., pupillometry), or performance deficits (i.e., reaction time). Subjective sleepiness can be subdivided into state measures, which are sensitive to abrupt changes caused, for example, by sleep deprivation, and trait measures, which primarily measures the respondents' general tendency to experience sleepiness. There are few scientific publications concerning sleepiness in the HEMS, and the few existing findings are ambiguous. Furthermore, the quality of the existing research is often limited due to low response rate (Müller et al. 2014), and low external validity caused by variations in shift systems across countries and agencies (Guyette et al. 2013). In addition, there seems to exist a discrepancy between results resting on measures of subjective sleepiness and those reflecting performance and objective measures of sleepiness (Müller et al. 2014; van Dongen et al. 2003). Furthermore, an appraisal of the fluctuation in sleepiness is important and could have implications for safety and health, for both personnel and patients. Consequently, knowledge about the effects of working long hours and consecutive shifts on sleepiness of pilots and HEMS crew members is thus essential. This current field study was conducted among pilots and HEMS crew members working for the Norwegian Air Ambulance (NAA). The NAA operated 9 out of 12 bases in Norway, including 10 of total 13 helicopters. The specific aim of the present study was to examine sleepiness in pilots and HEMS crew members before, during, and after a work week by administering subjective as well as objective measures of sleepiness. We hypothesized that sleepiness scores (measured with the Accumulated Time with Sleepiness Scale) would be higher during the work week, compared to the week before and after work (H1). Considering the work week, we expected that sleepiness (measured with the Accumulated Time with Sleepiness Scale, the Karolinska Sleepiness Scale, reaction time, and response accuracy) would increase over the work week (H2). We also hypothesized that during a day, the crew would report more sleepiness (measured with the Karolinska Sleepiness Scale) at the end of the wake period (H3). Finally, we expected that the crew members with larger amount of work (number of missions/training sessions and total work time) on duty would report higher sleepiness scores (measured with the Accumulated Time with Sleepiness Scale and the Karolinska Sleepiness Scale) compared to those with medium work amount (H4).

Method

Participants

The data derived from a study among workers in the NAA. All pilots and HEMS crew members ($n = 70$) working on all nine bases operated by the NAA were invited to participate in the study which started during the fall 2014. A total of 61 pilots and HEMS crew members agreed to participate in the first data collection, yielding a response rate of 87.1%. Of all the workers who participated in the first data collection, 59 were invited to take part in a second study that took place in spring/summer of 2015. In all, 50 workers agreed to participate, yielding a response rate of 84.7%. The current study presents data from the second data collection comprising 50 pilots and HEMS crew members, as we expected more activity during the summer weeks.

Procedure

The data collection was conducted during the spring and summer of 2015 and took part over 3 consecutive weeks: the week before work, the work week, and the week after work. The shift schedule starts with a 7-day work week followed by 14-day off duty, then 7-day on duty followed by 21-day off duty. The shift starts and ends at 10.00 on Monday morning, where the crew commutes either the day before or on the same day as the shift start. There are geographical differences between the bases, and the crew of those that are placed in rural areas often need to commute over longer distances. The crew operates missions both at day and night throughout the year. During the work week, the crew lives together on the bases with all necessary facilities, including separate bedrooms, exercise room, kitchen, and a living area with TV. The fatigue risk management system includes flight and work limits, divided into flight time and active work time approved by the Civil Aviation Authority of Norway. Flight time refers to time spent in the helicopter and active work time starts when an alarm goes off and ends 1 h after completed flight. Maximum flight time is 7 h in a consecutive 24 h period, 12 h in a consecutive 48 h period, and 30 h in a 7-day period. The maximum active work time is 14 h during a consecutive 24 h period and 30 h during a consecutive 72-h period. If the crew reaches a limit, they need to go off flight duty for 8 h before returning. In addition to providing medical service by helicopter, the HEMS crew members sometimes drive a rapid response car to close-by locations. The workers completed a questionnaire on their first duty day. Furthermore, they kept wake diaries for the 3 weeks and performed a reaction time test several times during the work week. The study included data from the mission log reported by the bases.

Instruments

Questionnaire

The questionnaire included demographic and background variables such as sex, age, marital status, and children living at home. It also covered questions about sleep need, sleep problems related to work schedule (ranging from none to very much), degree of sufficient sleep at work (ranging from never to very often), frequency of work weeks with less than 5 h of sleep (ranging from the occasional work week to every work week), caffeine, nicotine, commute, and second jobs.

Epworth Sleepiness Scale (ESS)

The ESS (Johns 1991) is an 8-item scale that measures the subject's general tendency to sleep or doze off in eight different situations. The scale is thus a subjective trait measure of sleepiness with a 4-point scale, yielding a total score between 0 and 24. Scores higher than 10 indicate excessive daytime sleepiness. The ESS demonstrated good internal consistency with an alpha reliability at 0.84. The ESS was administered once, on the first duty day.

Mission log

An overview of all the missions, training sessions, and the amount of time spent in active work was provided by the NAA. The workload variable included both missions and training sessions. Total work time (TWT) was calculated from the time the alarm went off to the time they landed after a mission. If a training session was conducted, the TWT was calculated from when the training session started to the time they landed back at the base. Based on tertiles, categorical variables were made for workload and TWT. Night work was defined as mission taking place between 24:00 and 07:00, including those missions that started before midnight and ended after midnight.

Sleepiness measured with wake diary

The Accumulated Time with Sleepiness (ATS) scale (Gillberg et al. 1994) is designed as a method for integrating measures of subjective sleepiness over longer time periods. Occurrence and duration (proportion of the wake period when the symptom was present, ranging from 0 to 100%) of specific symptoms of sleepiness during the wake period are rated. Six items were used in the present study, including "heavy eyelids", "feeling gravel-eyed", "difficulty in focusing your eyes", "irresistible sleepiness", "reduced performance", and "periods where you were fighting sleep". The scale is regarded as a state measure of sleepiness. Mean scores of week and days were calculated for each item, and a good internal consistency was demonstrated with an alpha reliability at 0.92. The ATS was sent by postal mail to the participant's home and was administered every day, before bedtime, for all 3 weeks.

The Karolinska Sleepiness Scale (KSS; Akerstedt and Gillberg 1990) consists of a 9-point graded, scale measuring subjective sleepiness rated from 1 = very alert, 3 = alert, 5 = neither alert nor sleepy, 7 = sleepy but no problems staying awake to 9 = very sleepy, fighting sleep, effort to stay awake. A score of seven or more indicates excessive sleepiness. The scores 2, 4, 6, and 8 are not verbally anchored. The KSS assesses state sleepiness and the participants completed the KSS every other hour while awake during the work week. Mean scores were calculated for each duty day and every other hour awake during the duty days.

Sleepiness measured with reaction time test

A task based on the Posner-cue-target paradigm was included as an objective measure of reaction time, inhibition and accuracy (Gundersen et al. 2007; Posner and Driver 1992) and was programmed using the standard version of E-Prime 2.0. (Psychology Software Tool). The task was administered on a laptop and the participants were instructed to complete the test while sitting down in a comfortable position, in quiet surroundings. During testing, the participants were told to fixate on a crosshair between two rectangular frames on the screen. When a target stimulus appeared in either of the frames, the participants were instructed to hit the 'D' (when stimulus appeared in left frame) or 'L' (when stimulus appeared in right frame) on the keyboard as fast as they could. The frames would sometimes be broadened (i.e., a cue) before the target stimulus appeared, which the participants were told to ignore. There were three categories incorporated in the test: “no cue”, “valid cue”, and “invalid cue”. “No cue” implied that the target stimulus appeared in one of the frames without any cue. In the “valid cue” category, the target stimulus appeared in a broadened frame, while in the “invalid cue” category, the target stimulus appeared in the opposite to the broadened frame. The test lasted for 4 min and 40 s and 168 target stimuli were presented during each test session. Each of the target stimuli was presented for 500 ms and the rest intervals between each stimulus were randomized and lasted for 600–1400 ms. The cue appeared 200 ms or 400 ms before the target stimulus was presented. The distribution of the target stimuli was 16.7% for “no cue”, 16.7% for “invalid cue”, and 66.6% for “valid cue”. Reaction time (RT) and response accuracy (RA) for each category were calculated. The participants completed the test five times during the work week: in the evening the first day at work, in the morning at midweek, in the evening at midweek, in the morning at the end of the work week, and in the evening at the end of the work week. They were instructed to take the evening tests right before bedtime and the morning tests within an hour after wake time.

Data analyses

All statistical analyses were conducted using SPSS version 25. A linear mixed model approach was applied to produce unbiased estimates of variance and covariance parameters (West et al. 2014). In the analysis of ATS over the 3 weeks, week was included as a fixed factor, where the second week (work week) was set as reference. The analysis of ATS during the work week included day, workload, and TWT as fixed factors. The analysis of KSS during the work week included day, time of day, workload, and TWT as fixed factors. At day 1, 24:00 in the time of day variable, medium workload, and medium TWT were set as reference categories in the two latter analyses. The effect of bases was adjusted for in the analysis. In the analysis of reaction time, fixed effect for test points was modelled. Subjects were included as a random factor in all analyses. Alpha values less than 0.05 were considered as statistically significant.

Missing data

On the six items from the ATS scale, missing data comprised 8.8% of the total in heavy eyelids, 8.8% of feeling gravel-eyed, 9.0% of difficulty in focusing your eyes, 8.9% of irresistible sleepiness, 8.7% of reduced performance, and 8.8% of periods, where you were fighting sleep. The proportion of missing data on the KSS was 6.5%, and for reaction time test, the proportion of missing data was 43.2% (108 out of 250 individual tests). Data on the reaction time test were missing at random, with no evident pattern in terms of distribution around timepoints.

Results

Descriptive statistics

Twenty-five pilots and 25 HEMS crew members participated in the study, representing nine different bases across Norway. In all, the sample consisted of 49 (98.0%) males and one female (2.0%). The mean age was 43.8 years (SD = 7.2), range 29–59 years. In all, 90.0% ($n = 45$) were married or cohabiting and 78.0% ($n = 39$) had children living at home. A total of 86.0% ($n = 43$) reported getting less than 5 h of sleep on duty occasionally or sometimes, 92.0% ($n = 46$) reported little or no problems related to sleep at work, and 80.0% ($n = 40$) reported getting enough sleep on duty. Data on intake of caffeine, use of nicotine, and characteristics about their commute are presented in

Table 1 Descriptive statistics regarding means of caffeine and nicotine consumptions, commute, commute length, and day of commute, reported in terms of number of participants (n) and percentages (%) among pilots and HEMS crew members in Norway ($N = 50$)

	n (%)
Caffeine on duty[a]	
No caffeine	2 (4.1)
1–2 cups	2 (4.1)
3–6 cups	35 (71.4)
≥ 7 cups	10 (20.4)
Smoke	
Yes	0 (0.0)
No	48 (100.0)
Snuff	
Yes	7 (14.6)
No	41 (85.4)
Means of commute	
Walk/bicycle	3
Car	34
Bus/train	16
Plane	18
Other	4
Commute length	
< 1 h	14 (29.8)
1–3 h	16 (34.0)
3–6 h	15 (31.9)
6–12 h	2 (4.3)
Commute day	
The day before first duty	1 (2.1)
The same day as first duty	46 (97.9)

[a]Cups of coffee, tea, cola, or energy drink, containing caffeine

Table 1. The mean ESS score was 7.1 (SD = 3.9). In all, 20 workers had a second job with a mean employment percentage of 22.4% (SD = 14.86), range 2–50%. During the work week, mean workload (number of missions and training sessions combined) was 17.3 (SD = 6.1), ranging from 5 to 30. Of these, 1.4 (SD = 1.0) was night work ranging from 0 to 4 during the work week. The mean TWT was 25.2 h (SD = 8.8) during the work week. TWT ranged from 7.1 to 48.0 h.

Sleepiness measured with wake diary

Sleepiness measured with Accumulated Time with Sleepiness (ATS) across 3 weeks

There were significant main effects of week on all six ATS components: heavy eyelids F (2, 907) = 10.1, $p < 0.001$ [estimated marginal means (SEM) week 1: 9.06 (1.76), week 2: 5.61 (1.75), week 3: 8.31 (1.78)], feeling gravel-eyed F (2, 911) = 4.81, $p < 0.01$ [estimated marginal means (SEM) week 1: 3.49 (0.983), week 2: 2.07 (0.981), week 3: 3.69 (1.0)], difficulty in focusing your eyes F (2, 910) = 5.01, $p < 0.01$ [estimated marginal means (SEM) week 1: 2.58 (0.779), week 2: 1.32 (0.778), week 3: 2.70 (0.795)], irresistible sleepiness F (2, 906) = 5.37, $p < 0.01$ [estimated marginal means (SEM) week 1: 5.54 (1.53), week 2: 3.44 (1.53), week 3: 5.50 (1.55)], reduced performance F (2, 916) = 13.9, $p < 0.001$ [estimated marginal means (SEM) week 1: 4.67 (0.759), week 2: 1.78 (0.756), week 3: 3.76 (0.781)], and periods where you were fighting sleep F (2, 907) = 6.28, $p < 0.01$ [estimated marginal means (SEM) week 1: 5.67 (1.65), week 2: 3.76 (1.65), week 3: 5.96 (1.67)], see Table 2 for estimates. When comparing HEMS crew members (M = 1.67, SD = 6.09) and pilots (M = 2.82, SD = 9.47), the pilots had slightly higher scores on the ATS item "difficulty in focusing your eyes" ($p < 0.05$).

Sleepiness measured with Accumulated Time with Sleepiness (ATS) during work week

There were no significant differences in the sleepiness scores for the six ATS components during the work week. Neither workload nor TWT affected these scores. The main effects of day on each ATS component were: heavy eyelids F (6, 276) = 0.419, $p = 0.866$, feeling gravel-eyed F (6, 277) = 0.707, $p = 0.645$, difficulty in focusing your eyes F (6, 278) = 0.823, $p = 0.553$, irresistible sleepiness F (6, 274) = 1.55, $p = 0.161$, reduced performance F (6, 281) = 1.14, $p = 0.340$, and periods where you were fighting sleep F (6, 276) = 1.59, $p = 0.150$. The main effects of workload on each ATS component were: heavy eyelids F (2, 284) = 1.75, $p = 0.175$, feeling gravel-eyed F (2, 296) = 1.69, $p = 0.186$, difficulty in focusing your eyes F (2, 303) = 2.91, $p = 0.056$, irresistible sleepiness F (2, 280) = 1.55, $p = 0.215$, reduced performance F(2, 312) = 1.81, $p = 0.166$, and periods where you were fighting sleep F (2, 282) = 2.31, $p = 0.101$. The main effects of TWT on each ATS component were: heavy eyelids F (2, 284) = 0.201, $p = 0.818$, feeling gravel-eyed F (2, 296) = 0.010, $p = 0.990$, difficulty in focusing your eyes F (2, 302) = 0.186, $p = 0.830$, irresistible sleepiness F (2, 280) = 0.024, $p = 0.977$, reduced performance F (2, 310) = 0.041, $p = 0.960$, and periods where you were fighting sleep F (2, 282) = 0.089, $p = 0.915$, see Table 3 for estimated marginal means.

Sleepiness measured with the Karolinska Sleepiness Scale (KSS) during work week

There were significant main effects on the KSS for day F (6, 2539) = 4.66, $p <$. 001, time of day F (8, 2535) = 49.61, $p < 0.001$, workload F (2, 2561) = 4.93,

Table 2 Effects of weeks on subjective sleepiness, measured by the Accumulated Time with Sleepiness (ATS), across 3 weeks among pilots and HEMS crew members in Norway ($N = 50$)

	Week 1 Estimate (SEM)	Week 2[a]	Week 3 Estimate (SEM)
ATS			
Heavy eyelids	3.45 (0.804)***		2.70 (0.847)**
Feeling gravel-eyed	1.42 (0.558)*		1.62 (0.589)**
Difficulty in focusing your eyes	1.27 (0.476)**		1.38 (0.501)**
Irresistible sleepiness	2.09 (0.722)**		2.06 (0.761)**
Reduced performance	2.89 (0.559)***		1.98 (0.589)**
Periods, where you were fighting sleep	1.91 (0.661)**		2.20 (0.696)**

Results are from linear mixed models including multilevel estimates and standard error of the means (SEM)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

[a]The second week (work week) represents the reference group

Table 3 Estimated marginal means (M) and standard error of the mean (SEM) on the Accumulated Time with Sleepiness (ATS) across 7 work days, workload and total work time (TWT) among pilots and HEMS crew members in Norway ($N = 50$)

	Day M (SEM)							Workload M (SEM)			TWT M (SEM)		
	1	2	3	4	5	6	7	Lower	Medium	Higher	Lower	Medium	Higher
ATS													
1	5.21 (2.06)	4.71 (2.02)	6.15 (2.01)	5.97 (2.02)	5.48 (1.99)	7.11 (2.02)	4.59 (2.00)	7.29 (1.69)	5.55 (1.94)	3.97 (1.97)	5.19 (1.98)	5.41 (1.74)	6.21 (1.77)
2	2.42 (1.15)	0.687 (1.11)	2.35 (1.10)	1.60 (1.11)	1.14 (1.09)	2.98 (1.11)	1.54 (1.10)	2.96 (0.801)	1.63 (1.03)	0.774 (1.06)	1.78 (1.07)	1.86 (0.857)	1.73 (0.874)
3	1.21 (0.923)	− 0.104 (0.881)	1.36 (0.870)	0.638 (0.876)	0.645 (0.866)	2.20 (0.873)	0.653 (0.864)	2.30 (0.583)	0.554 (0.810)	-0.024 (0.825)	0.681 (0.830)	0.871 (0.641)	1.28 (0.651)
4	1.25 (1.93)	2.84 (1.90)	4.92 (1.89)	3.64 (1.90)	3.90 (1.88)	5.53 (1.89)	2.71 (1.88)	5.00 (1.65)	2.97 (1.83)	2.66 (1.87)	3.47 (1.87)	3.68 (1.69)	3.48 (1.71)
5	1.76 (0.863)	0.717 (0.833)	2.67 (0.823)	0.828 (0.829)	1.27 (0.810)	2.61 (0.817)	0.960 (0.817)	2.59 (0.523)	1.16 (0.749)	0.886 (0.770)	1.39 (0.774)	1.59 (0.582)	1.66 (0.593)
6	1.14 (1.93)	3.37 (1.90)	4.59 (1.89)	4.19 (1.89)	4.21 (1.88)	5.53 (1.88)	2.73 (1.88)	5.40 (1.66)	3.20 (1.84)	2.44 (1.86)	3.48 (1.87)	3.94 (1.70)	3.62 (1.72)

ATS 1 heavy eyelids, *ATS 2* feeling gravel-eyed, *ATS 3* difficulty in focusing your eyes, *ATS 4* irresistible sleepiness, *ATS 5* reduced performance, *ATS 6* periods were you were fighting sleep

Table 4 Effects of days (1–7), time of days (08:00–24:00), workload, and total work time (TWT) during the work week for subjective sleepiness, measured by the Karolinska Sleepiness Scale (KSS) among pilots and HEMS crew members in Norway ($N = 50$)

	Estimate (SEM)	M (SEM)
Days		
1[a]		3.23 (0.165)
2	– 0.464 (0.096)***	2.76 (0.165)
3	– 0.283 (0.098)**	2.94 (0.164)
4	– 0.405 (0.097)***	2.82 (0.164)
5	– 0.342 (0.098)***	2.88 (0.164)
6	– 0.285 (0.103)**	2.94 (0.164)
7	– 0.316 (0.102)***	2.91 (0.165)
Time		
08	– 0.751 (0.136)***	3.38 (0.183)
10	– 1.50 (0.116)***	2.63 (0.169)
12	– 1.77 (0.112)***	2.34 (0.166)
14	– 1.77 (0.111)***	2.35 (0.166)
16	– 1.53 (0.111)***	2.57 (0.166)
18	– 1.27 (0.112)***	2.84 (0.166)
20	– 1.39 (0.111)***	2.74 (0.166)
22	– 0.880 (0.111)***	3.25 (0.166)
24[a]		4.13 (0.170)
Workload		
Low	0.096 (0.086)	3.06 (0.154)
Medium[a]		2.96 (0.162)
High	– 0.194 (0.089)*	2.77 (0.163)
TWT		
Low	– 0.081 (0.079)	2.81 (0.163)
Medium[a]		2.89 (0.156)
High	0.185 (0.074)*	3.08 (0.156)

Results are from linear mixed models including estimates, standard error of the mean (SEM) and estimated marginal means (M)

Adjusted for the effect of base

The KSS scores are based on means for each day and each hour

$*p<0.05$, $**p<0.01$, $***p<0.001$

[a]Day 1, time 24:00, medium workload, and medium TWT represents the reference groups

$p < 0.01$, and TWT F (2, 2559) = 4.48, $p < 0.05$. Day 1 had higher scores compared to the remaining 6 days. For time of day, the KSS scores were significantly higher at midnight (24:00) compared to all the other hours. Those with higher workload reported lower KSS scores compared to those with medium work load, while those with higher TWT reported higher KSS scores compared to those with medium TWT, see Table 4 for estimates and estimated marginal means. There was no significant difference between the scores for the HEMS crew members and pilots ($p = 0.06$).

Sleepiness measured with reaction time test

Reaction time test (response time and response accuracy) during work week

There was no significant main effect of time for $RT_{no\ cue}$ F (4, 98) = 1.58, p = 0.186, $RT_{valid\ cue}$ F (4, 98) = 1.30, p = 0.276, and $RT_{invalid\ cue}$ F (4, 98) = 0.972, p = 0.427, across five test points over the work week. There was no significant main effect of time for $RA_{no\ cue}$ F (4, 98) = 0.407, p = 0.803, $RA_{valid\ cue}$ F (4, 98) = 1.84, p = 0.127, and $RA_{invalid\ cue}$ F (4, 98) = 0.600, p = 0.664 across five test points over the work week.

Discussion

The sleepiness scores measured by the ATS were lowest in the work week, compared to the weeks at home before and after work. During the work week, the highest sleepiness scores measured by the KSS were reported on the first day of work. However, there was no change during the week in terms of reaction time and response accuracy. Over the course of the day, the highest sleepiness scores measured by the KSS were reported at midnight. Having higher workload was associated with lower sleepiness measured by the KSS compared to medium workload, whereas having longer TWT was associated with higher sleepiness scores measured by the KSS, compared to a medium TWT. The crew members felt less sleepy during their work week, compared to their weeks off (both before and after). Consequently, there was no support for the first hypothesis stating that sleepiness scores would be higher during the work week, compared to the week before and the week after work. We expected opposite findings in line with other studies (Mullins et al. 2014; Akerstedt and Wright 2009). However, the crew in the present study was living at the base during the work week which relieves them of social and domestic obligations. With available base facilities such as separate bedrooms, an exercise room and a living room, the crew likely gets sufficient rest and leisure between the missions and training sessions. This may explain the lower sleepiness scores. Excessive sleepiness during free days has been found in other studies among shift workers (Härmä et al. 2018), suggesting that accumulated sleep deprivation during the work period may become manifest on days off work. However, these studies are only partially comparable to the present due to differences in sample population and work schedule predictability. In addition, the current study's sample had a minimum of 14-day off between the work weeks. This means that the crew already had at least 1-week off work before the first assessment week in this study. Still, higher sleepiness score compared to the work week was found, although overall sleepiness levels at all 3 weeks were low. This indicates that the slightly higher sleepiness scores in the first week, stems from sources other than work. When at home, the workers have domestic obligations, including children to take care of which could be a possible factor explaining these scores. In compliance with this, Gregory et al. (2010) found that 26% of air medical pilots reported child care as a factor that affected the ability to sleep. Furthermore, some of the crew holds second jobs during their weeks off, which could explain why the sleepiness scores are slightly higher the weeks off duty. Nevertheless, it is important to emphasize that the overall sleepiness scores across all 3 weeks were low considering that the ATS scale range from 0 to 100. Hence, although higher, the sleepiness the week before and after work was not deemed clinically elevated. A comparison between the pilots and the HEMS crew members revealed a somewhat higher score for the pilots on the "difficulty in focusing your eyes" item. As the HEMS crew members are more likely to have a higher workload due to accompanying on the rapid response car, this result seems thus reasonably. However, both the scores were low indicating that neither pilots nor HEMS crew members experienced much sleepiness across the 3 weeks. The crew reported the highest sleepiness scores on the first day at work, compared to the following 6 duty days. Furthermore, the reaction time tests did not change over the course of the work week. Given these results, the second hypothesis must be rejected, postulating that subjective and objective measures of sleepiness would increase during the work week. As the hypothesis suggested, one would expect that the crew members became sleepier over the course of the work week, due to accumulated sleep deprivation caused by shift work and the work load itself (Akerstedt and Kecklund 2005). However, there are other studies, indicating that the workers adapt to shift work during the work period. Bjorvatn et al. (2006) found a decrease in sleepiness scores, both subjective and objective, over a week of night shift offshore. However, these results could be explained by a shift in the circadian rhythm due to the week of night work. Based on the mission log in the present study, it is evident that most of the missions took place during daytime and a circadian alteration is not likely, although this should be investigated in future studies. Despite the fact that the study of Bjorvatn and colleagues comprised oil rig workers who worked a week of night shift followed by a week of day shift, that occupational group still has some similarities to our sample, such as work facilities. The offshore workers live on the oil rig during their work period, and they work shift and have extended work hours. These results could suggest that the work facilities affect sleepiness levels in a positive way during the work period, despite having work schedules that often have been reported to impact sleepiness negatively. One possible explanation for the higher sleepiness scores on the first duty day could also be related to commuting. The majority of the crew reported using a car as a commuter and using 1–6 h to commute. Furthermore, almost all commuted the same day as the shift started. As the shift started at 10.00 in the morning and having up to 6 h of commute by car on the same day, it would imply that the workers needed to wake up very early at the first work day. For this reason, commute length could explain why the workers display higher sleepiness scores on the first duty day. This should receive some attention, as subjective sleepiness is associated with an increase in automobile accidents (Bioulac et al. 2017). Another possible explanation to our findings is that phase delay due to late bedtime and rise time might have occurred during the preceding weekend (Yang et al. 2001). Nevertheless, the subjective sleepiness scores were all distributed on the lower part of the scale; thus, statistically significant results must be interpreted with prudence. The practical meaning of this result should also be considered with caution, as the difference from the remaining duty days was small. The crew members showed no evidence of increased sleepiness over the course of the work week, as measured with reaction time tests. Interestingly, there was no increase on the first duty day despite having higher subjective sleepiness scores. In accordance with other studies, this could suggest that alertness is maintained, by keeping low response time and high response accuracy, despite reporting subjective sleepiness (Cullip et al. 2014; Thomas et al. 2006). The previous studies report a decrease in performance due to sleepiness (Myers et al. 2017), while others report no difference in sleepiness and/or performance despite working long shifts (Amann et al. 2014; Guyette et al. 2013). The results from the current study provide support for the latter findings. However, it is worth mentioning that the test could activate the participants by being a distinct new component in their work environment and explain the lack of change in reaction time and response accuracy. Over the course of a duty day, the crew members did report changes in levels of sleepiness. The highest sleepiness scores were not surprisingly reported at midnight, significantly different from the other timepoints of the day. Therefore, the third hypothesis, stating that crew would experience increased sleepiness at the end of the wake period, was supported. Still, the average sleepiness scores were low and distributed between the 'very alert' and 'neither sleepy nor alert' step of the scale. The distribution of the sleepiness scores resembles an oscillation in sleepiness that follows the circadian rhythm, rather than sleepiness due to work schedule (Borbély et al. 2016). The previous studies on shift work have indicated that night work and morning work are associated with sleepiness during the day, and that rotational work, rather than fixed work, is associated with higher sleepiness (Thun et al. 2016). Furthermore, a study on air plane operations found that sleepiness levels increased after flight duty (Yen et al. 2009). The work characteristics of the air ambulance service involve both night work and early morning work, often in a rotational manner, which make the present study relevant. An interpretation of the present result is that the work schedule did not affect the sleepiness score over the course of a duty day. Two variables were created based on the mission log: workload (total number of missions and training sessions during the work week), and TWT (total time in hours and minutes spent actively working during the 7-day shift). Both were made categorical and based on tertiles. Having higher workload was associated with lower sleepiness scores compared to having medium workload. In contrast, having higher TWT was associated with higher sleepiness scores compared to medium TWT. This gives partial support for the fourth hypothesis, postulating that the crew members with larger amount of work (both workload and TWT) would have higher sleepiness scores compared to those with medium work amount. These results may indicate that the activation related to more missions reduced sleepiness levels, while the activation related to longer missions did not. This is in accordance with other studies, where higher sleepiness occurred on the longest missions during a day (Amann et al. 2014; Powell et al. 2008). Nevertheless, again, the sleepiness was overall low, indicating that the crew and pilots were sufficiently alert.

Overall, the results suggest that the crew members experienced low levels of state sleepiness despite having 7-day shift on the base and unpredictable working hours. Furthermore, the trait measure of sleepiness revealed low levels (ESS = 7.1), compared to the Norwegian male population, where the mean ESS score is 7.4 (Pallesen et al. 2007). The results obtained on the state measures of sleepiness were all within the non-pathological/non-problematic level. This is in agreement with studies from other fields that share similar work schedules and arrangements, including offshore workers, tunnel workers, and construction workers (Bjorvatn et al. 2006; Forberg et al. 2010; Persson et al. 2006).

Strengths and limitations

Some strengths and limitations of the present study should be noted. The use of both wake diaries and reaction time tests to assess sleepiness constitutes an asset. Objective measurement enabled a higher control of motivational effects that is associated with self-report. As studies suggest, there exists some discrepancies in awareness of sleepiness levels and results of objective tests, this was also taken into consideration as both subjective and objective measures of sleepiness was included (Myers et al. 2017; van Dongen et al. 2003). Another strength was related to the two types of subjective sleepiness scales that were administered. The ATS assesses sleepiness retrospectively, while the KSS is administered in situ. In situ questionnaire ensures a more accurate rating of sleepiness by avoiding biases, such as memory bias. Furthermore, it was also an asset having both a global measure of a day (ATS) and time-specific measures throughout the day (KSS). These factors could explain why we with the ATS did not find any difference in sleepiness throughout the work week, while this was detected with the KSS. Finally, the length of the study and amount of data collected per participant allowed for a comprehensive assessment of fluctuation in the dependent variables. Regarding the analysis, the use of linear mixed models approach enabled use of available data for units where timepoint data were missing, which represents a statistical advantage. Field studies provide insight relevant to groups that are not easily accessible. These studies have limitations regarding control and sample size, but represent a strength in terms of knowledge of groups that are of specific operational interest. Finally, another strength was related to the response rate, which was high. The findings in the current study could be vulnerable to the « healthy worker effect », as the sample reflects a group that assumingly cope well and prefer a shift work setting as workers not coping well are assumed to not initiate or to be selected out of shift work by time. Given the health and educational requirements needed to fulfill the work demands in the present occupations, these workers are even more strongly selected. The results could consequently reflect the characteristics of this group rather than the effect of the work schedule. Furthermore, it would be preferable with a larger sample size, especially for the objective data. The generalizability represents a limitation that applies for field studies in general; thus, both the low sample size and the highly selected occupational group make the results difficult to generalize to other occupational groups. However, the results could be of interest to similar groups from the same occupation in general or for other groups that share the same type of work schedule. Due to some missing data on the reaction time test, the amount of registrations on each occasion was quite limited which could affect the results. However, it is challenging to conduct field studies on such selected groups due to the special work setting and the unpredictable work sessions. Objective measures such as reaction time tests could, therefore, have been given lower priority. Future studies should focus on adaptable means of securing higher participation regarding objective testing in occupational settings. However, the total number of reaction time tests in the present study was still adequate, with 142 out of 250 tests completed. In addition, studies on sleep deprivation show that the effect of the deprivation increases, as the length of the test increases (Lo et al. 2016). The test length of 4 min and 40 s may, therefore, have been too short to reveal any real impact of sleepiness. The study lacks injury and accident data on HEMS operations, which could serve as an objective measure of sleepiness in certain incidents. In addition, the findings should also be interpreted in light of the special context (e.g., work schedule and job characteristics) and study limitations (e.g., selection bias). Future studies on this topic should assess and adjust for chronotype in the analyses.

Conclusion

The present study revealed that the overall sleepiness scores were low during all 3 test weeks. When comparing the 3 weeks, the lowest sleepiness levels were found for the work week. There was a small difference across work days, in which subjective sleepiness scores were highest the first duty day. No change in the reaction time tests was evident during the work week. The crew members reported being most sleepy at midnight, compared to all the other timepoints over the course of a duty day. Regarding workload and TWT, having larger workload was associated with lower sleepiness scores, while having higher TWT was associated with higher sleepiness score, both compared to the medium category. To the author's knowledge, this study is unique in being one of the first field studies on this occupational group that included both subjective and objective measures of sleepiness over an extended period. Overall, our findings indicate that the work setting and schedules for this particular occupational group do not seem to negatively affect the sleepiness levels.

Acknowledgements The research project was supported by grant from the Norwegian Air Ambulance Foundation.

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest.

Human participants The study was conducted in accordance to the Declaration of Helsinki and approved by the Regional Committee for Medical and Health Research Ethics of Western Norway (REK-Vest; project no. 2014/593), as well as the Norwegian Social Data Service (NSD). All participants provided written informed consent before enrollment. This article does not contain any studies with animals performed by any of the authors.

References

Akerstedt T, Gillberg M (1990) Subjective and objective sleepiness in the active individual. Int J Neurosci 52(1–2):29–37

Akerstedt T, Kecklund G (2005) The future of work hours—the European view. Ind Health 43(1):80–84

Akerstedt T, Wright KP (2009) Sleep loss and fatigue in shift work and shift work disorder. Sleep Med Clin 4(2):257–271

Amann U, Holmes A, Caldwell J, Hilditch C (2014) Sleep and sleepiness of pilots operating long-range airplane emergency medical missions. Aviat Space Environ Med 85(9):954–959
Bioulac S, Franchi J-AM, Arnaud M, Sagaspe P, Moore N, Salvo F, Philip P (2017) Risk of motor vehicle accidents related to sleepiness at the wheel: a systematic review and meta-analysis. Sleep. https://doi.org/10.1093/sleep/zsx134
Bjorvatn B, Stangenes K, Øyane N, Forberg K, Lowden A, Holsten F, Akerstedt T (2006) Subjective and objective measures of adaptation and readaptation to night work on an oil rig in the North Sea. Sleep 29(6):821–829
Borbély AA, Daan S, Wirz-Justice A, Deboer T (2016) The two-process model of sleep regulation: a reappraisal. J Sleep Res 25(2):131–143
Caruso CC (2014) Negative impacts of shiftwork and long work hours. Rehabil Nurs 39(1):16–25
Cullip T, Hudson A, Lyon R, McWhirter E (2014) Testing alertness of Helicopter Emergency Medical Service (HEMS) crews—a feasibility study (Report) 22(9026)
Forberg K, Waage S, Moen B, Bjorvatn B (2010) Subjective and objective sleep and sleepiness among tunnel workers in an extreme and isolated environment: 10-h shifts, 21-day working period, at 78 degrees north. Sleep Med 11(2):185–190
Gillberg M, Kecklund G, Akerstedt T (1994) Relations between performance and subjective ratings of sleepiness during a night awake. Sleep 17(3):236–241
Goode JH (2003) Are pilots at risk of accidents due to fatigue? J Saf Res 34(3):309–313
Gregory KB, Winn W, Johnson K, Rosekind MR (2010) Pilot fatigue survey: exploring fatigue factors in air medical operations. Air Med J 29(6):309–319
Gundersen H, Helland CA, Raeder MB, Hugdahl K, Wester K (2007) Visual attention in patients with intracranial arachnoid cysts. J Neurol 254(1):60–66
Guyette FX, Morley JL, Weaver MD, Patterson PD, Hostler D (2013) The effect of shift length on fatigue and cognitive performance in air medical providers. Prehosp Emerg Care 17(1):23–28
Härmä M, Kecklund G (2010) Shift work and health—how to proceed? Environ Health 36(2):81–84
Härmä M, Sallinen M, Ranta R, Mutanen P, Müller K (2002) The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. J Sleep Res 11(2):141–151
Härmä M, Karhula K, Puttonen S, Ropponen A, Koskinen A, Ojajärvi A, Kivimäki M (2018) Shift work with and without night work as a risk factor for fatigue and changes in sleep length: a cohort study with linkage to records on daily working hours. J Sleep Res 28:e12658
Harrington JM (2001) Health effects of shift work and extended hours of work. Occup Environ Med 58(1):68–72
Johns MW (1991) A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep 14(6):540–545
Lo JC, Ong JL, Leong RL, Gooley JJ, Chee MW (2016) Cognitive performance, sleepiness, and mood in partially sleep deprived adolescents: the need for sleep study. Sleep 39(3):687–698
Müller R, Wittmer A, Drax C (2014) Aviation risk and safety management: methods and applications in aviation organizations, 2014th edn. Springer International Publishing, Cham
Mullins HM, Cortina JM, Drake CL, Dalal RS (2014) Sleepiness at work: a review and framework of how the physiology of sleepiness impacts the workplace. J Appl Psychol 99(6):1096
Myers JA, Powell DMC, Aldington S, Sim D, Psirides A, Hathaway K, Haney MF (2017) The impact of fatigue on the non-technical skills performance of critical care air ambulance clinicians. Acta Anaesthesiol Scand 61(10):1305–1313
National Sleep Foundation (2018) What is shift work? https://www.sleepfoundation.org/shift-work/content/what-shift-work. Accessed 18 Sep 2018
Pallesen S, Nordhus IH, Omvik S, Sivertsen B, Tell GS, Bjorvatn B (2007) Prevalence and risk factors of subjective sleepiness in the general adult population. Sleep 30(5):619
Persson R, Ørbaek P, Kecklund G, Akerstedt T (2006) Impact of an 84-hour workweek on biomarkers for stress, metabolic processes and diurnal rhythm. Scand J Work Environ Health 32(5):349
Posner MI, Driver J (1992) The neurobiology of selective attention. Curr Opin Neurobiol 2(2):165–169
Powell D, Spencer MB, Holland D, Petrie KJ (2008) Fatigue in two-pilot operations: implications for flight and duty time limitations. Aviat Space Environ Med 79(11):1047–1050
Previc FH, Lopez N, Ercoline WR, Daluz CM, Workman AJ, Evans RH, Dillon NA (2009) The effects of sleep deprivation on flight performance, instrument scanning, and physiological arousal in pilots. Int J Aviat Psychol 19(4):326–346
Radstaak M, Geurts SA, Beckers DG, Brosschot JF, Kompier MA (2014) Work stressors, perseverative cognition and objective sleep quality: a longitudinal study among Dutch Helicopter Emergency Medical Service (HEMS) pilots. J Occup Health 56(6):469–477
Sallinen M, Kecklund G (2010) Shift work, sleep, and sleepiness—differences between shift schedules and systems. Scand J Work Environ Health 36(2):121–133
Sallinen M, Laukkanen-Nevala P, Olkinuora A, Puttonen S, Vanttola P, Virkkunen I (2018) Working hours, sleep and alertness in HEMS personnel in Finland. In: Lecture presented at Biomedicum Helsinki
Swanson LM, Arnedt JT, Rosekind MR, Belenky G, Balkin TJ, Drake C (2011) Sleep disorders and work performance: findings from the 2008 National Sleep Foundation Sleep in America poll. J Sleep Res 20(3):487–494
Thomas F, Hopkins RO, Handrahan DL, Walker J, Carpenter J (2006) Sleep and cognitive performance of flight nurses after 12-hour evening versus 18-hour shifts. Air Med J 25(5):216–225
Thun E, Bjorvatn B, Akerstedt T, Moen BE, Waage S, Molde H, Pallesen S (2016) Trajectories of sleepiness and insomnia symptoms in Norwegian nurses with and without night work and rotational work. Chronobiol Int 33(5):480–489
van Dongen HPA, Maislin G, Mullington JM, Dinges DF (2003) The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep 26(2):117–126
Wagstaff A, Lie J (2011) Shift and night work and long working hours—a systematic review of safety implications. Scand J Work Environ Health 37:173–185
West BT, Welch KB, Galecki AT (2014) Linear mixed models, 2nd edn. CRC Press, Arbor
Yang C-M, Spielman AJ, D'Ambrosio P, Serizaw S, Nunes J, Birnbaum J (2001) A single dose of melatonin prevents the phase delay associated with a delayed weekend sleep pattern. Sleep 24(3):272–281
Yen J-R, Hsu C-C, Yang H, Ho H (2009) An investigation of fatigue issues on different flight operations. J Air Transp Manag 15(5):236–240

CHRONOBIOLOGY INTERNATIONAL
2021, VOL. 38, NO. 1, 129–139
https://doi.org/10.1080/07420528.2020.1802288

Subjective and objective sleep among air ambulance personnel

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ABSTRACT

The present study aimed to investigate the effects of shift work on sleep among pilots and Helicopter Emergency Medical Service crew members (HCM) in the Norwegian Air Ambulance. Sleep was assessed by diaries and actigraphy during a workweek (24 h duty for 7 consecutive days) in the winter season and a workweek during the summer season in pilots and HCM (N = 50). Additionally, differences in sleep were studied between the week before work, the workweek, and the week after work in both seasons. Results indicated that bedtime was later (p <.001) and time spent in bed (p <.05) was shorter during the summer, compared to the winter, season. The workers delayed the sleep period in the workweek, compared to the week before (winter: p <.001, summer: p <.001) and the week after (winter: p <.05-.001, summer: p <.001). They spent more time in bed during the workweek, compared to the week before (winter: p <.001, summer: p <.01) and after (winter: p <.001, summer: p =.37). Further, the workers had longer wake after sleep onset during the workweek, compared to the week before (winter: p <.001, summer: p <.01) and the week after (winter: p <.01, summer: p <.01). Finally, the workers had lower sleep efficiency during the workweek recorded by actigraphy compared to the week before (winter: p <.01, summer: p <.001) and the week after (winter: p <.01, summer: p <.001). According to the sleep diaries the total sleep time was 7:17 h in the winter and 7:03 h in the summer season. Overall, the sleep was somewhat affected during the workweek, with delayed sleep period, longer wake after sleep onset, and lower sleep efficiency compared to when off work. However, the workers spent more time in bed during the workweek compared to the weeks off, and they obtained over 7 h of sleep in both workweeks. Our findings suggest that the pilots and the HCM sleep well during the workweek, although it affected their sleep to some extent.

ARTICLE HISTORY
Received 25 March 2020
Revised 18 July 2020
Accepted 22 July 2020

KEYWORDS
Sleep; shift work; air ambulance; pilot; HCM; crew; sleep diary; actigraphy

Introduction

Shift work can be defined as work whereby the workers succeed each other at the workplace following certain patterns, entailing work outside normal daytime, including evenings, nights, and/or weekends (European Directive 2003/88/EC 2003). Concerns regarding the negative effects of shift work date back to the 13th century (Bjerner et al. 1948). Shift work is associated with acute sleep loss related to early morning and night shifts, with reported reductions of 2–4 h following night shifts (Kecklund and Axelsson 2016; Sallinen and Kecklund 2010). A characteristic of shift work is extended working hours, often denoted as work beyond 48 h per week (Harrington 2001). Such work schedules often imply activity at a time when the internal circadian clock is set at rest and inactivity, and sleep at times when the worker is biologically set to be awake, typically causing sleepiness as well as insomnia (Rosenwasser and Turek 2015). Studies indicate that extended working hours are associated with lower sleep efficiency and less total sleep time (Rhéaume and Mullen 2018; Swanson et al. 2011). Notably, sleep disruption has several well-known detrimental effects related to health, safety, and performance (Folkard and Tucker 2003; Medic et al. 2017).

Helicopter Emergency Medical Services (HEMS) are increasing becoming a part of the Emergency Medical Service (EMS) throughout the world (Butler et al. 2010; Taylor et al. 2011). The main indication for HEMS use is severe disease or trauma of patients in need of advanced medical treatment and/or rapid transport to hospital. HEMS is an on-demand medical service, and for the HEMS crew the shift work schedule entails work at irregular hours. Although studies indicate that certain

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types of accidents, and consequently missions, could be predicted to some extent (Folkard 1997; Manfredini et al. 2009; Smolensky et al. 2015), generally there is low predictability in terms of their quantity, type, and duration. The organization of HEMS varies considerably between countries regarding both work schedules and settings. The work schedules of different HEMS in Europe vary greatly – from 12, 24, and 48 h shifts in Netherland and Finland (Radstaak et al. 2014; Sallinen et al. 2018), and up to 7 consecutive 24 h shifts in Norway and Austria (Zakariassen et al. 2019). Some live on the helicopter base, while others commute every day, and there are also differences regarding the extent to which the crew takes on missions after dark (Radstaak et al. 2014; Zakariassen et al. 2019).

HEMS operations in Norway are scheduled as 24 h shifts over 7 consecutive d as an around-the-clock operation, with work periods generally being busier during summer compared to winter (Luftambulansetjenesten 2020). During the 7 consecutive d shifts the workers engage in on-call work and respond to incoming missions. This implies the crew lives on the base and takes on missions 24/7 for one week. There is large seasonal variation in the duration of daylight in Norway. For example, in the capital Oslo (59.91°N), duration of daylight in November is ~8.5 h and in May it is ~16.0 h, whereas in places north of 67.30°N there is polar night (winter) and midnight sun (summer). Still, there is a dearth of studies investigating what effect the work schedule has on sleep and if this varies by season. HEMS operations add additional risk to patient and crew. Between 1st January 2014 and 30th of May 2020, the Accident Investigation Board Norway (2020) identified 1 accident resulting in 2 fatalities and 1 seriously injured. However, numbers of near-misses are unknown. Given the large potential damage of accidents in HEMS compared to ground-based EMS, this is an area that demands attention. Lack of sleep alters cognitive functions that could affect workers' ability to perform satisfactorily and may potentially compromise safety (Monk and Folkard 1992). This could result in detrimental effects for both crew and patients. Still, we previously found HEMS crew members performed well on a reaction time test throughout the workweek (Flaa et al. 2019), suggesting that they were not sleep deprived. More research on the effects of consecutive shifts and long working hours on the sleep of pilots and HEMS crew members (HCM) is deemed essential, and longitudinal and multilevel studies on sleep in a work setting have been called for in order to fill the knowledge gaps in this research area (Litwiller et al. 2017).

Accordingly, the aim of the present study was to examine sleep in pilots and HCM on 24 h duty for 7 consecutive d, during two different work periods covering both the winter and summer season. We also examined how total work time and workload affected sleep variables during the workweek. In addition, we studied sleep over three consecutive weeks including the week at home before work, the workweek, and the week at home after work, in both the winter and the summer season. This enabled an examination of potential differences in sleep across the different weeks on and off work across seasons.

Methods

Study setting

In the Norwegian Air Ambulance, shifts are arranged in a 7d duty period followed by 14d off duty, before a new 7d duty period, followed by 21d off duty, period. The shift schedule is identical in all bases involved in the study. The crew lives together on the base during the duty week and conducts on-demand missions around the clock throughout the year. The duty week starts at 10:00 h on Monday morning and ends at 10:00 h following Monday. Workers commute either the same day as the shift starts or the day before. On the base, the crew has access to all the necessary facilities, including a kitchen, exercise room, and living room with TV. Each worker has his/her own separate bedroom with private bathroom, and can control the indoor light using a switch, outdoor light by blackout curtains, and temperature using a radiator. An operating fatigue risk management system (FRMS) includes flight and active work time limitations approved by the Civil Aviation Authority of Norway. The FRMS comprises a human-designed system based on institutional standards for flight- and duty time limitations. Flight time includes missions and training sessions. Active work time includes flight time, administrative duties, technical tasks, and rapid response car missions to locations near the base. The limits for active work time are 14 h over a consecutive 24 h period and 30 h over a 3d period. The maximum flight time is 7 h over a 24 h period, 12 h in a consecutive 48 h period, and 30 h over 7d. If the active work time limit is reached within a 24 h period, the crew (including both the pilot and HCM) must go off flight duty for 8 h. If a crew reaches their limit, the missions are allocated to the nearest base when appropriate. In 2015, the accessibility level was 98% (National Air Ambulance Service of Norway 2015).

Procedure

Sleep data were collected over three consecutive weeks (the week before work, the workweek, and the week after work) in two separate periods, one in the winter (October – December) and one in the summer season (May – July). The pilots and HCM completed sleep diaries and wore actigraphs every day throughout the 6 test weeks. On their first duty day, pilots and HCM also completed a questionnaire assessing various sociodemographic variables. The total amount of time the worker would need to complete the daily diaries was 5–10 min, and, therefore, it was not thought to alter their habits and behaviour notably.

Participants

The study took place in fall/winter of 2014 and spring/summer of 2015. All pilots and HCM (n = 70) at the 9 air ambulance bases in Norway operated by the Norwegian Air Ambulance were invited to take part in the study. One of the 9 bases was located in the northern part of Norway, the remaining were located in Trondheim or further south. In all, 61 (87%) workers participated in the fall/winter data collection. Two participants were excluded from the spring/summer data collection, due to changes in their work responsibilities and organizational tasks inconsistent with the remaining sample. Thus, 59 subjects were invited to participate in the spring/summer data collection. A total of 50 (85% of invited/71% of total) pilots and HCM participated in this spring/summer data collection.

Instruments

Questionnaire

The questionnaire contained items assessing background and demographic variables, such as age (y), sex (male/female), marital status (married/cohabiting yes/no), children living at home (yes/no), second job (yes/no), chronotype (1 – pronounced morning type – 5 pronounced evening type), smoking (yes/no), use of sleeping aid (yes/no; which), and physical health (1 very good – 5 very poor). A question regarding sleep need (in h) was also included. All descriptive data were collected during the workweek in the winter season.

Sleep measured with sleep diary

Daily estimates of prior sleep periods were obtained with a modified version of a sleep diary published by Morin (1993). The sleep diary was completed after waking up in the morning for three consecutive weeks in both data collection periods. In all, 50 workers completed a sleep diary in both data collection periods. Based on the diary data, we calculated the crew's bed time, wake-up time, time in bed, wake after sleep onset, sleep efficiency (total sleep time as a percentage of time in bed), as well as total sleep time.

Sleep measured with actigraphy

Sleep/wake profiles were measured by wrist actigraphy (Actiwatch 2, Respironics Inc.), a device that has the size and appearance of a wristwatch (CamNtech Ltd 2008). The actigraph is considered to provide valid and accurate estimates of sleep patterns in normal, healthy adults (Sadeh et al 2011; Stone and Ancoli-Israel 2011). Further, reliability of the actigraph is found to increase with extended study length (> 5 d; Sadeh et al 2011). It was programmed to record individual sleep/wake profiles continuously in 1-min epochs, using the medium (default) threshold for sleep and wake period detection provided by the software Actiware. For medium threshold, the sensitivity threshold (number of activity counts used to identify wake) was 40 per epoch. Sleep start and sleep end threshold were 10 min of immobility. The workers were instructed to wear the actigraph on the wrist of the non-dominant arm continuously for all three weeks, and to press an event button on the device to indicate bedtime and wake-up time. Scoring was built upon the steps proposed by Chow et al. (2016), including a hierarchical approach emphasizing event markers and then activity levels. For the actigraphs in the present study, the light markers were not set up due to storage limitations. Thus, the scoring was based on sleep diary and activity level in those cases where the event markers were absent (30% of the observations). To avoid overestimation of sleep length, the wake-up time was based on self-reported wake-up time despite low activity level in the absence of an event marker, as workers might stay in bed after awakening. Variables such as bedtime, wake-up time, time in bed, wake after sleep onset, sleep efficiency, and total sleep time were calculated. In total, 50 participants wore the actigraph throughout both data collection periods, but due to technical and user-related issues, data of only 46 out of the 50 actigraphs were eligible for inclusion in the analyzes.

Mission log

The Norwegian Air Ambulance provided a complete overview of the total work time, missions, and training sessions. Total work time represents the actual amount of time spent on missions and training sessions. The work time of a mission was calculated from when an alarm went off to initiate the operation until the helicopter landed after the operation. The work time generated from a training session was calculated from the start of the session to the time of landing back at the base. The total work time variable applied in the analysis was a combination of the two. The workload variable comprised the mean number of missions and training sessions collapsed. Categorical variables were formed for total work time and workload, based on tertiles in order to examine how different levels of work time affect sleep variables. Night work was defined as missions occurring between 24:00 and 07:00 h, including missions that started before, but ended after midnight. However, a mission that started before 07:00 h but end after that clock time, e.g., 05:00 and ended 08:00 h, was not categorized as a night mission.

Data analyzes

Continuous data are summarized as mean (±SD) for symmetric data, median (quartiles) for non-symmetric data, and categorical variables as numbers; n (%). In order to explore the workers' sleep during the workweeks and the weeks off work, linear-mixed models (LMM) were applied to generate unbiased estimates of variance (West et al. 2014). LMM is a generalization of traditional linear regression models, adjusting for the inner correlation structure in the data that results from multiple observations on the same individual. LMM for the four variables of bedtime, wake-up time, time in bed, and total sleep time as dependent variables were fitted. The four sleep variables were examined for both sleep diary and actigraphy data. Analyzes compared both the sleep patterns between the two workweeks in winter versus summer, and over three consecutive weeks (before work, workweek, and after work) during the winter season and the summer season, separately. Total work time and workload were included as fixed factors in the relevant analyzes, and the medium category was set as the reference (based on tertiles). For the analyzes over three weeks, the second week (workweek) was set as the reference. From these analyzes, regression coefficients (unstandardized b-scores) were reported. Due to skewed residuals for the sleep efficiency and wake after sleep onset variables, a Mann-Whitney U test was applied to examine sleep during the two workweeks (winter vs. summer), and a Friedman ANOVA with Wilcoxon post-hoc test was applied for the data analysis over the three weeks, with Bonferroni correction for multiple testing. For the latter analyzes, z-scores were reported. p-values $< .05$ were considered statistically significant. The statistical analyzes were conducted using SPSS (version 25).

Missing data

Missing data on the sleep items comprised between 0.0% and 11.9% for the sleep diary, and between 2.4 and 12.5% for actigraphy. Data were marked as missing in the sleep diaries if the workers had forgot to fill out certain columns. Data were marked as missing in the actigraph recordings if the worker had removed the actigraph, or due to technical issues related to the actigraph. Missing data were only calculated for the sleep periods. Complete case analysis with more than 5% missing data introduces bias of unknown direction and magnitude (Dong and Peng 2013), and multiple imputation was conducted in order to perform Friedman ANOVA. Ten imputed datasets were generated based on the distribution of the existing data, and results averaged to one value. This was conducted individually per worker for the relevant weeks (workweek for workweek, etc.). Dependent variables included in the imputation were wake after sleep onset and sleep efficiency.

Ethics

The study was conducted in line with the Declaration of Helsinki and was approved by the Regional Committee for Medical and Health Research Ethics of Western Norway (REK-Vest; project no. 2014/593), as well as the Norwegian Social Data Service (NSD). It also followed the ethical standards and methods outlined by Portaluppi et al. (2010). All participants provided written informed consent before participating.

Results

Descriptive statistics

A total of 25 pilots and 25 HCM took part in the study, median (quartiles) age was 43 y (38–48 y), and all, but one, participants were men (98%). The mean (SD) work experience in the HEMS occupation was 9.4 (7.9) y. Forty-five (90%) of the workers reported cohabitation or marriage, and 39 (78%) had children living at home. In all, 20 workers (40%) had a second job with the percentage of full-time employment ranging from 2 to 50%. On the chronotype 14 workers (28%) reported being neither morning nor evening type, 13 (26%) were more morning than evening type, 13 (26%) were more evening than morning type, 4 (8%) were morning type, and 4 (8%) evening type. None of the workers were smokers, while 1 worker (2%) used melatonin as a sleeping aid. In all, 43 workers (90%) rated their physical health as good or very good. The mean (SD) self-reported sleep need (h:min) was 7:12 (0:45).

Workload and total work time

The mean (SD) workload in terms of number of missions during the workweek was 14.5 (7.3), ranging from

4 to 32, in the winter season, and 17.6 (6.3), ranging from 5 to 30, in the summer season. Of these, night work made up 1.8 (1.6) in the winter season, and 1.6 (1.1) in the summer season. A total of 16% (winter season) and 6% (summer season) of the workers performed ≥ 3 nighttime missions. Overall, the mean (SD) total work time spent on missions and trainings sessions during the workweek was 18:41 h (08:41 h) during the winter season, and 25:22 h (09:05 h) during the summer season. The difference between the winter- and summer season was statistically significant for both total work time and workload (both $p < .001$).

Sleep during the workweek in the winter season compared with the workweek in the summer season

Summary measures for sleep variables derived from the sleep diary and actigraphy are presented in Table 1 and Figure 1. Bedtime was significantly later during the workweek in the summer season than in the winter season (sleep diary: $p < .001$, actigraphy: $p < .01$; Table 2). Those with higher amount of total work time had later bedtime in the summer season as compared to those with medium amount (sleep diary: $b = 0.59$, $p < .001$, actigraphy: $b = 0.53$, $p < .01$), but those with lower amounts of total work time did not have later bedtime (sleep diary: $b = -0.12$, $p = .45$, actigraphy: $b = -0.17$, $p = .33$). Workload did not affect bedtime, neither assessed by sleep diary (lower category: $b = -0.22$, $p = .20$, higher category: $b = 0.22$, $p = .27$) nor actigraphy (lower category: $b = -0.31$, $p = .10$, higher category: $b = 0.35$, $p = .10$). According to the sleep diary data only, workers spent less time in bed during the summer as compared to the winter season ($p = .03$). During summer, those with higher workload spent less time in bed compared to those with medium workload ($b = -0.61$, $p = .02$), but not compared to those with lower workload ($b = -0.24$, $p = .31$). There was no difference regarding time in bed between the total work time categories (lower category: $b = 0.40$, $p = .07$, higher category: $b = -0.13$, $p = .56$). In addition, there was no significant difference between the winter season and summer season in terms of wake-up time, wake after sleep onset, sleep efficiency, or total sleep time. [Figure 1, Tables 1 and 2 near here]

Sleep over three weeks during the winter season

Bedtime was significantly later during the workweek, compared to the week before (sleep diary and actigraphy: $p < .001$) and after work (sleep diary: $p = .01$, actigraphy: $p < .001$; Table 2). Wake-up time was later during the workweek, compared to the week before (sleep diary and actigraph: $p < .001$) and after work (sleep diary and actigraphy: $p < .001$). Time in bed was longer during the workweek, compared to the week before work (sleep diary: $p < .001$, actigraphy: $p < .01$), but only significant for sleep diary after work ($p < .001$). Wake after sleep onset was higher during the workweek, compared to the week before (sleep diary and actigraphy: $p < .001$) and after work (sleep diary and actigraphy: $p < .01$). For actigraphy data only, sleep efficiency was lower during the workweek, compared to the week before ($p < .01$) and after work ($p < .01$). Exclusively for sleep diary data, total sleep time was longer during the

Table 1. Descriptive characteristics of sleep variables across three weeks during winter season and summer season.

	Week before work		Workweek		Week after work	
	Sleep diary	Actigraphy	Sleep diary	Actigraphy	Sleep diary	Actigraphy
Bedtime[a]						
Winter	24:06 (1:16)	24:11 (1:21)	24:33 (1:20)	24:54 (1:30)	24:18 (1:19)	24:28 (1:47)
Summer	24:14 (1:12)	24:28 (1:17)	24:54 (1:18)	01:13 (1:23)	24:22 (1:23)	24:33 (1:19)
Wake-up time[a]						
Winter	07:30 (1:16)	07:23 (1:23)	08:36 (1:26)	08:26 (1:25)	07:55 (1:26)	07:46 (1:30)
Summer	07:36 (1:21)	07:23 (1:25)	08:42 (1:34)	08:37 (1:37)	07:56 (1:25)	07:48 (1:23)
Time in bed[a]						
Winter	7:41 (1:13)	7:12 (1:21)	8:16 (1:28)	7:31 (1:30)	7:53 (1:14)	7:21 (1:22)
Summer	7:39 (1:22)	6:55 (1:12)	8:01 (1:38)	7:23 (1:34)	7:53 (1:23)	7:14 (1:17)
Wake after sleep onset[b]						
Winter	0:05 (0:00–0:15)	0:40 (0:29–0:55)	0:05 (0:00–0:30)	0:44 (0:30–1:15)	0:05 (0:00–0:15)	0:41 (0:28–1:01)
Summer	0:05 (0:00–0:11)	0:36 (0:26–0:48)	0:05 (0:00–0:20)	0:44 (0:28–1:16)	0:05 (0:00–0:15)	0:40 (0:28–0:56)
Sleep efficiency[b]						
Winter	92.5 (87.0–95.5)	86.6 (81.8–89.9)	92.5 (85.7–96.3)	84.4 (75.6–89.3)	93.0 (86.5–96.0)	85.5 (79.8–89.7)
Summer	93.4 (88.7–96.1)	87.4 (83.4–90.8)	91.9 (84.1–96.0)	85.4 (76.7–89.4)	93.7 (88.1–96.4)	86.2 (82.0–90.5)
Total sleep time[a]						
Winter	6:54 (1:17)	6:05 (1:22)	7:17 (1:26)	6:01 (1:24)	7:05 (1:17)	6:09 (1:23)
Summer	6:55 (1:21)	5:59 (1:12)	7:03 (1:30)	5:57 (1:27)	7:08 (1:33)	6:09 (1:16)

The sleep variables derive from sleep diary and actigraphy.
All sleep variables are presented in h:min format, except for sleep efficiency which is presented in percentages.
[a]Mean (SD)
[b]Median (quartiles)

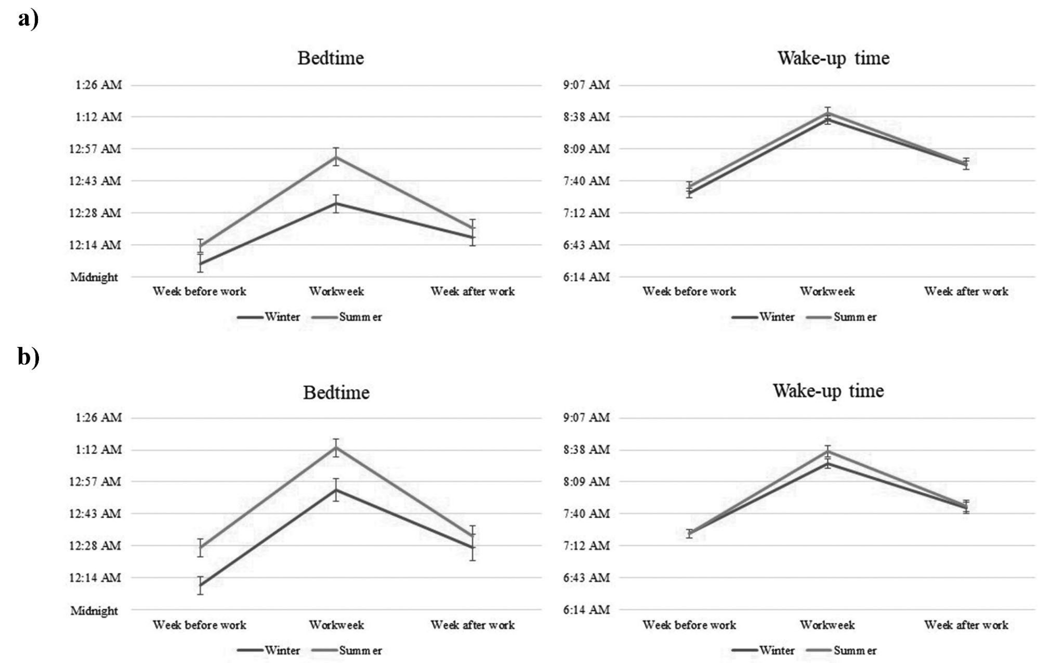

Figure 1. Mean scores of bedtime and wake-up time over three weeks during winter and summer season, measured by a) sleep diary and b) actigraphy. Error bars represent standard error.

Table 2. Estimates and standard scores for sleep variables between winter season and summer season workweek, and during the week before work, the workweek, and the week after work.

	Workweeks		Three-week period				
	Winter season	Summer season[ʃ]	Week before work		Workweek[ʃ]	Week after work	
			Winter	Summer		Winter	Summer
Sleep diary							
Bedtime[a]	−.359***		−.417***	−.676***		−.220*	−.569***
Wake-up time[a]	−.089		−1.079***	−1.078***		−.663***	−.764***
Time in bed[a]	.263*		−.588***	−.340**		−.393***	−.104
Wake after sleep onset[b]	−.033		−4.039***	−3.469**		−3.704**	−3.747**
Sleep efficiency[b]	−.722		−.524	−2.237		−1.680	−1.837
Total sleep time[a]	.212		−.409***	−.132		−.229*	.080
Actigraphs							
Bedtime[a]	−.339**		−.694***	−.764***		−.483***	−.685***
Wake-up time[a]	−.198		−1.027***	−1.220***		−.629***	−.859***
Time in bed[a]	.134		−.327**	−.461***		−.163	−.164
Wake after sleep onset[b]	−.477		−4.604***	−5.286***		−3.753**	−4.987***
Sleep efficiency[b]	−.781		−3.069**	−4.769***		−2.947**	−4.968***
Total sleep time[a]	.054		.069	.015		.141	.154

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
The sleep variables derive from sleep diary and actigraphy.
[a]The reported values are unstandardized b-scores from Linear Mixed Models.
[b]The reported values are z-scores from Mann Whitney U and Friedman ANOVA, post-hoc Wilcoxon. [ʃ] Represents the reference groups.

workweek, compared to the week before ($p < .001$) and after work ($p = .02$).

Sleep over three weeks during the summer season

Bedtime was significantly later during the workweek, compared to the week before (sleep diary and actigraphy: $p < .001$; Table 2) and after work (sleep diary and actigraphy: $p < .001$). Wake-up time was later during the workweek, compared to the week before (sleep diary and actigraph: $p < .001$) and after work (sleep diary and actigraphy: $p < .001$). Time in bed was longer during the workweek, compared to the week before (sleep diary: $p < .01$, actigraphy: $p < .001$), but not the week after work. Wake after sleep onset was higher during the workweek, compared to the week before (sleep diary: $p < .01$, actigraphy: $p < .001$) and after work (sleep diary: $p < .01$, actigraphy: $p < .001$). In line with actigraphy (not sleep diary) data, sleep efficiency was lower during the workweek, compared to the week before ($p < .001$) and after work ($p < .001$). There was no significant difference in total sleep time between the three weeks.

Discussion

In the present study, we examined sleep in pilots and HCM, comparing two workweeks, one in the winter and one in the summer season. Additionally, we also investigated sleep over 3 consecutive weeks; the week before work, the workweek, and the week after work, during both seasons.

During the workweeks, workers went to bed later and spent less time in bed in the summer compared to the winter season. Several factors can explain this. The general Norwegian population has been found to be 14% more active during the summer than during the winter season (Hansen et al. 2015), which could lead to more accidents and thus more missions and active work hours for the pilots and HCM. Later bedtime and less time in bed could thus be due to missions appearing at late hours, and therefore delay bedtime. This is also reflected by our findings showing a higher prevalence of missions, workload, and total work time during the summer compared to the winter season. More specifically, we found that total work time was positively associated with bedtime. Workload was inversely associated with time in bed. Considering bedtime, previous studies on seasonal change in sleep show mixed results. Some studies have found later bedtime in the winter season (Friborg et al. 2012; Hashizaki et al. 2018), whereas other corroborate the present findings, showing later bedtime during summer (Garde et al. 2014; Quante et al. 2019). However, it should be noted the samples of the above-mentioned studies, in contrast to the sample in the current study, were mainly comprised of daytime workers and adolescents. It can be assumed that lack of morning light in the winter as well as evening light exposure in the summer may delay the circadian rhythm (Khalsa et al. 2003). Hence, differences in timing of light exposure and latitude may explain the previous conflicting results. As there are large variations in hours of daylight across the country, in both seasons, there could be more pronounced seasonal effects for the workers living and working in areas with particularly reduced or increased hours of daylight. Future studies should therefore explore if the impact of season on sleep is moderated by latitude. In the present study, the latest mean bedtime recorded by actigraphy was 01:13 h during the summer season. Consequently, the overall bedtime is not very late regarding the work setting. Considering seasonal variation related to time in bed, previous studies indicate more time spent in bed during winter, corroborating the present findings (O'Connell et al. 2014).

There were some novel findings between the workweek and off weeks (before and after) in both seasons, showing workers delayed the sleep period during both workweeks. As previously discussed, missions in the evening and night can contribute to later bedtimes. One could also speculate that absence of early morning missions could enable the workers to sleep in, explaining this delay. Yet, the evidence suggests there were not many night missions (mean number 1.8 per workweek in the winter season and 1.6 per workweek in the summer season). The social effect of living together with colleagues on the base could also affect sleep habits in the absence of missions and social obligations from the family, where the crew could delay their sleep period similar to what normal daytime workers are able to do on the weekends (Petersen et al. 2017).

For both the winter and summer season, longer wake time after sleep onset and lower sleep efficiency were reported during the workweek compared to off weeks. Although the number of night missions was low, the crew still received potential missions and calls that would wake them during the night, thus contributing to more frequent nocturnal awakenings and lower sleep efficiency. Additionally, results from on-call experimental field studies have indicated that wake after sleep onset increases and sleep efficiency decreases in on-call groups, even when calls did not occur, probably because their mere anticipation (i.e., of missions) increased wakefulness (Wuyts et al. 2012; Ziebertz et al. 2017). Receiving calls that are cancelled and the mere possibility of calls on base could hence explain our results. However, we do not have data on received calls on base. Further, the results for sleep efficiency were found only for actigraphic data; thus, these results must be interpreted with prudence.

Despite delaying the sleep period, experiencing increased wake after sleep onset, and decreased sleep efficiency, the workers reported higher total sleep time during their workweek. This is opposite to what one might expect considering the literature linking shift work to reduced sleep length (Härmä et al. 2018; Swanson et al. 2011). However, prolonged sleep was only found for the winter season, where the number of missions was lower compared to the summer season. Fewer missions and less daylight could enable the workers to sleep in if early morning missions or calls were absent. This is contrary to previous studies where no difference between seasons was reported regarding sleep duration (Friborg et al. 2012; Garde et al. 2014), while a literature review of clinical reports concluded mixed results concerning the effect of season on sleep duration (Jay et al. 2015). More missions and daylight during the summer season may diminish the difference in sleep length between the workweek and off weeks, which might explain why sleep duration was found to be elevated during the workweek during winter, only. One could further speculate that more missions lead to more rumination, which has been found to explain the association between work stressors and poor sleep in the Dutch HEMS (Radstaak et al. 2014). If workers experienced more rumination during their busier summer than winter season, this could explain why the difference between the off weeks and workweek was not evident during the summer season. However, the total amount of sleep the workers obtained in the summer season was 7:03 h, indicating the sleep duration was within normal limits (Hirshkowitz et al. 2015). It should also be noted this finding was only evident in the sleep diary data, and the difference in total sleep time between the two workweeks was only 14 min. The self-reported sleep need was 7 h and 12 min. When we analyzed the total sleep time obtained across the 3 weeks in both seasons from the sleep diary (Table 1), it was evident the workers obtained the least amount of sleep during the week before work. The workweek and week after work were more alike in terms of total sleep time. Interestingly, the workers slept longer than their self-reported sleep need during the workweek in the winter season. The findings suggest the workweek did not reduce total sleep time, when comparing it to the weeks at home.

The workers increased their time spent in bed during both workweeks, where the difference was more distinct when comparing the workweek to the week at home before work. This supports the finding for sleep duration during the workweek in the winter season. Considering the summer season, spending more time in bed despite no difference between the weeks in terms of sleep length could indicate that the workers were busier and had somewhat more disrupted sleep during the workweek of this season. Nonetheless, they still spent 8 h in bed, sleeping 7 of these during the summer season. The average nocturnal sleep duration for Norwegian men is 6:52 h (Ursin et al. 2005), suggesting that adequate amounts of sleep seemed to have been obtained. A previous study comparing Norwegian and Austrian HEMS pilots found that 24% of the Austrian and 71% of Norwegian pilots report using sleep as a mitigating measure against sleepiness, suggesting on-duty Norwegian pilots are better at using sleep facilities when needed (Zakariassen et al. 2019). Additionally, 78% of the workers in the present study had children living at home and 40% kept a second job during their weeks off work. Living on the base during the workweek could, therefore, possibly protect against such domestic, social, and work obligations at home. Given the selection criteria (educational and health) required to fulfill the job demands in this occupation, these workers represent a highly selected group. Further, workers also had ~9 y of experience, which could indicate they are tolerant to the demands of this unique occupation and thus be representative of a survival cohort, and as such may serve as a mitigating effect. This, together with well-equipped and separate sleep-facilities, could help preserve sleep despite the potential effect of pending calls and other mission-related activities during the night.

In summary, the HEMS workers seemed to be well adjusted to the work setting despite sleep being affected to some extent. This is in line with other studies suggesting that workers adapt to work settings that require changes in sleeping conditions and location (Bjorvatn et al. 2006; Forberg et al. 2010). However, one needs to be aware of workers who have short and fragmented sleep. Thus, there is a need in operative occupations for constant development of fatigue risk management systems that may detect and mitigate the risk for these cases. Hence, fatigue risk management systems should continue to develop in order to minimize the potential harm that work schedules and settings pose for the crew and patients' safety.

Strengths and limitations

Several strengths and limitations of the present study deserve mention. The sample was predominantly male, with only one female participant. This was expected, as the HEMS is a male-dominant occupation. However, one must take caution generalizing the findings to other populations with higher numbers of females. Also, as the crew live and work together during their workweek, it would be also of interest to measure social interaction and its potential effect on sleep. Of all 9 bases in the study, one was located in the north of Norway, while the remaining was located in the south. There are large variations in hours of daylight between north and south, thus potential differences in this regard are unaccounted for in the analyzes. However, as we wanted to examine this occupational group collectively, use of data from all bases was deemed essential. Thus, the results must be interpreted with cation. Another limitation is lack of information about home versus base location, between which there could be variations in daylight, potentially affecting our findings. Further, the findings in the present study could also be influenced by the “healthy worker effect”, as the workers are a cohort who cope well with the shift schedule and are individuals who are not assumed to self-select out of this work setting. Being workers in the air ambulance services, an additional resilience could be present given the choice of the air ambulance work compared to other types of work. The focus of the present study was to investigate how sleep at the group level was influenced by work and free periods as well as season. We acknowledge that in the occupational group studied there might be individual differences in sleep in general and also when it comes to the impact of work and free periods as well as season. Future studies should, therefore, investigate individual differences regarding this. The coherence between sleep diaries and the actigraphic recordings was not always good. There were discrepancies, both minor and major. Compared to the sleep diary data, actigraphy measures were consistently later for bedtime, earlier for wake-up time, and higher for wake after sleep onset and the number of awakenings, and lower for time in bed, total sleep time, and sleep efficiency. Such discrepancies have been reported previously by others (Curtis et al. 2019; Matthews et al. 2018). The actigraph scores sleep solely based on movement and could, therefore, affect how well it detects sleep and wakefulness. Generally, studies show that actigraphy has reasonably good sensitivity (ability to detect sleep), but rather poor specificity (ability to detect wake) (Sivertsen et al. 2006), although this is dependent both on the nature of the hardware and software (interpretative algorithms) used to the derive sleep parameters (Haghayegh et al. 2019). The threshold settings could also affect correspondence with diary data, where for the former we applied the default threshold. However, it is difficult to know which parameters, actigraphy or diary, have the largest bias. For this reason, the combination of both can provide valuable insight into sleep and awake periods. Further, the scoring of the actigraphs was based on bedtimes/rise times from the sleep diary data when event marker on the actigraphs were lacking. Although this was done according to guidelines that have been used in previous studies (Biddle et al. 2015), one could argue that actigraphy data by this process become less objective. However, the actigraph is still a widely used method for investigation of sleep and can be useful as long as one takes caution when interpreting the findings (Ancoli-Israel et al. 2003). The use of both subjective and objective measures is also regarded as a strength, as it provides a more nuanced insight into the workers’ sleep. Further, including objective sleep measures could help compensate for potential response biases in participants’ self-reported measures. Longitudinal data collection over 6 weeks in total represents another asset of the present study, as it enabled an investigation of sleep across several weeks before, during, and after work across two seasons. This field study also provided insight into an occupational group that is challenging to study, which represents an important ad-on to the literature.

Conclusion

The findings indicate a few seasonal differences in sleep, albeit sleep by and large was within normal values during both seasons. Sleep seemed to be somewhat more disrupted, and the workers had lower sleep efficiency, during workweeks than on off weeks according to the actigraph data. However, workers spent more time in bed at work compared to off work periods and even slept more during the workweek compared to off time during the winter season. Despite findings that the work setting affected sleep to some extent, the sleep variables overall suggest workers coped well with the duty schedule. Nevertheless, internal fatigue risk management systems should be continuously evolving in order to detect and handle individual cases of poor sleep that may be hidden by the averages.

Disclosure statement

The authors declare no conflicts of interest.

Funding

The Norwegian Air Ambulance Foundation funded the project.

Data availability

The data that support the findings of this study are available from the corresponding author, TAF, upon reasonable request.

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References

Accident Investigation Board Norway. 2020. Aviation. published reports. Oslo (Norway): Accident Investigation Board Norway; [accessed 2020 May 30]. https://www.aibn.no/Luftfart/Published-reports

Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollak CP. 2003. The role of actigraphy in the study of sleep and circadian rhythms. Sleep. 26(3):342–392. 10.1093/sleep/26.3.342

Biddle DJ, Robillard R, Hermens DF, Hickie IB, Glozier N. 2015. Accuracy of self-reported sleep parameters compared with actigraphy in young people with mental ill-health. Sleep Health. 1(3):214–220. doi:10.1016/j.sleh.2015.07.006

Bjerner N, Å H, Swensson Å 1948. Om natt- och skiftarbete (on night and shift work). Stockholm (Sweden): Statens Offentliga Utredningar. Report No: 51.

Bjorvatn B, Stangenes K, Øyane N, Forberg K, Lowden A, Holsten F, Åkerstedt T. 2006. Subjective and objective measures of adaptation and readaptation to night work on an oil rig in the North Sea. Sleep. 29(6):821–829. doi:10.1093/sleep/29.6.821

Butler DP, Anwar I, Willett K. 2010. Is it the H or the EMS in HEMS that has an impact on trauma patient mortality? A systematic review of the evidence. Emergency Med J. 27 (9):692–701. doi:10.1136/emj.2009.087486

CamNTech Ltd. 2008. Cambridgeshire (UK). [Accessed 2020 Aug 11]. https://www.camntech.com/

Chow CM, Wong SN, Shin M, Maddox RG, Feilds K-L, Paxton K, Hawke C, Hazell P, Steinbeck K. 2016. Defining the rest interval associated with the main sleep period in actigraph scoring. Nat Sci Sleep. 8:321. doi:10.2147/NSS.S114969

Curtis AF, Miller MB, Boissoneault J, Robinson M, Staud R, Berry RB, McCrae CS. 2019. Discrepancies in sleep diary and actigraphy assessments in adults with fibromyalgia: associations with opioid dose and age. J Sleep Res. 28(5): e12746. doi:10.1111/jsr.12746

Directive 2003/88/EC of the European parliament and of the council of 4 November 2003 concerning certain aspects of the organisation of working time. 2003. Offi J European Union. L299:9–11. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32003L0088

Dong Y, Peng CYJ. 2013. Principled missing data methods for researchers. SpringerPlus. 2(1):222.10.1186/2193-1801-2-222

Flaa TA, Harris A, Bjorvatn B, Gundersen H, Zakariassen E, Pallesen S, Waage S. 2019. Sleepiness among personnel in the Norwegian air ambulance service. Int Arch Occup Environ Health. 92(8):1121–1130. doi: 10.1007/s00420-019-10449-w

Folkard S. 1997. Black times: temporal determinants of transport safety. Accid Anal Prev. 29(4):417–430. 10.1016/S0001-4575(97)00021-3

Folkard S, Tucker P. 2003. Shift work, safety and productivity. Occup Med (Chic Ill). 53(2):95–101. doi:10.1093/occmed/kqg047

Forberg K, Waage S, Moen B, Bjorvatn B. 2010. Subjective and objective sleep and sleepiness among tunnel workers in an extreme and isolated environment: 10-h shifts, 21-day working period, at 78 degrees north. Sleep Med. 11 (2):185–190. doi:10.1016/j.sleep.2009.07.015

Friborg O, Bjorvatn B, Amponsah B, Pallesen S. 2012. Associations between seasonal variations in day length (photoperiod), sleep timing, sleep quality and mood: a comparison between Ghana (5) and Norway (69). J Sleep Res. 21(2):176–184. doi:10.1111/j.1365-2869.2011.00982.x

Garde AH, Hansen ÅM, Persson R, Österberg K, Ørbæk P, Karlson B, Olsen A, Kristiansen J. 2014. Month-to-month variation in sleep among healthy, Scandinavian daytime workers. Scand J Clin Lab Invest. 74(6):527–535. doi:10.3109/00365513.2014.913303

Haghayegh S, Khoshnevis S, Smolensky MH, Diller KR, Castriotta RJ. 2019. Performance comparison of different interpretative algorithms utilized to derive sleep parameters from wrist actigraphy data. Chronobiol Int. 36(12):1752-1760. doi:10.1080/07420528.2019.1679826

Hansen BH, Anderssen SA, Steene-Johannessen J, Ekelund U, Nilsen AK, Andersen ID, Dalene KE, Kolle E 2015. Fysisk aktivitet og sedat tid blant voksne og eldre i Norge – nasjonal kartlegging 2014-2015 (Physical activity and sedate time amound adults and elderly in Norway – national survey 2014–2015). Oslo (Norway): Helsedirektoratet. Report No.: IS-2367.

Härmä M, Karhula K, Puttonen S, Ropponen A, Koskinen A, Ojajärvi A, Kivimäki M. 2018. Shift work with and without night work as a risk factor for fatigue and changes in sleep length: a cohort study with linkage to records on daily working hours. J Sleep Res. 28(3):e12658. doi:10.1111/jsr.12658

Harrington JM. 2001. Health effects of shift work and extended hours of work. Occup Environ Med. 58 (1):68–72. doi:10.1136/oem.58.1.68

Hashizaki M, Nakajima H, Shiga T, Tsutsumi M, Kume K. 2018. A longitudinal large-scale objective sleep data analysis revealed a seasonal sleep variation in the Japanese population. Chronobiol Int. 35(7):933–945. doi:10.1080/07420528.2018.1443118

Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, Hazen N, Herman J, Katz ES, Kheirandish-Gozal L, et al. 2015. National sleep foundation's sleep time duration recommendations: methodology and results summary. Sleep Health. 1(1):40–43. doi:10.1016/j.sleh.2014.12.010.

Jay SM, Aisbett B, Sprajcer M, Ferguson SA. 2015. Sleeping at work: not all about location, location, location. Sleep Med Rev. 19:59–66.10.1016/j.smrv.2014.04.003

Kecklund G, Axelsson J. 2016. Health consequences of shift work and insufficient sleep. Bmj. 355:i5210. doi:10.1136/bmj.i5210

Khalsa SBS, Jewett ME, Cajochen C, Czeisler CA. 2003. A phase response curve to single bright light pulses in human subjects. J Physiol. 549(3):945–952. doi:10.1113/jphysiol.2003.040477

Litwiller B, Snyder LA, Taylor WD, Steele LM. 2017. The relationship between sleep and work: A meta-analysis. J Appl Psychol. 102(4):682. doi:10.1037/apl0000169

Luftambulansetjenesten. 2020. 2020 01 Flytid totalt. [accessed 2020 Feb 27]. http://www.luftambulanse.no/system/files/internett-vedlegg/2020_01_flytid_totalt.pdf.

Manfredini R, Manfredini F, Boari B, Bergami E, Mari E, Gamberini S, Salmi R, Gallerani M. 2009. Seasonal and weekly patterns of hospital admissions for nonfatal and fatal myocardial infarction. Am J Emerg Med. 27 (9):1097–1103. doi:10.1016/j.ajem.2008.08.009

Matthews KA, Patel SR, Pantesco EJ, Buysse DJ, Kamarck TW, Lee L, Hall MH. 2018. Similarities and differences in estimates of sleep duration by polysomnography, actigraphy, diary, and self-reported habitual sleep in a community sample. Sleep Health. 4(1):96–103. doi:10.1016/j.sleh.2017.10.011

Medic G, Wille M, Hemels ME. 2017. Short-and long-term health consequences of sleep disruption. Nat Sci Sleep. 9:151. doi:10.2147/NSS.S134864

Monk TH, Folkard S. 1992. Making shiftwork tolerable. London(UK): Taylor & Francis.

Morin CM. 1993. Insomnia: psychological assessment and management. New York (NY): Guilford Press.

National Air Ambulance Service of Norway. 2015. Annual report 2015. Bodø (Norway). [accessed 2020 May 30]. http://www.luftambulanse.no/system/files/internett-vedlegg/arsrapport_2015.pdf. National Air Ambulance Service of Norway.

O'Connell SE, Griffiths PL, Clemes SA. 2014. Seasonal variation in physical activity, sedentary behaviour and sleep in a sample of UK adults. Ann Hum Biol. 41(1):1–8. doi:10.3109/03014460.2013.827737

Petersen H, Kecklund G, D'Onofrio P, Axelsson J, Åkerstedt T. 2017. Thank god it's Friday–sleep improved. J Sleep Res. 26(5):567–571. doi:10.1111/jsr.12538

Portaluppi F, Smolensky MH, Touitou Y. 2010. Ethics and methods for biological rhythm research on animals and human beings. Chronobiol Int. 27(9–10):1911–1929. doi:10.3109/07420528.2010.516381

Quante M, Wang R, Weng J, Kaplan ER, Rueschman M, Taveras EM, Rifas-Shiman SL, Gillman MW, Redline S. 2019. Seasonal and weather variation of sleep and physical activity in 12–14-year-old children. Behav Sleep Med. 17 (4):398–410. doi:10.1080/15402002.2017.1376206

Radstaak M, Geurts SA, Beckers DG, Brosschot JF, Kompier MA. 2014. Work stressors, perseverative cognition and objective sleep quality: A longitudinal study among dutch helicopter emergency medical service (HEMS) pilots. J Occup Health. 56(6):469–477. doi:10.1539/joh.14-0118-OA

Rhéaume A, Mullen J. 2018. The impact of long work hours and shift work on cognitive errors in nurses. J Nurs Manag. 26(1):26–32. doi:10.1111/jonm.12513

Rosenwasser AM, Turek FW. 2015. Neurobiology of circadian rhythm regulation. Sleep Med Clin. 10(4):403–412. doi:10.1016/j.jsmc.2015.08.003

Sadeh A. 2011. The role and validity of actigraphy in sleep medicine: An update. Sleep Medicine Reviews. 15(4): 259–267. doi:10.1016/j.smrv.2010.10.001

Sallinen M, Kecklund G. 2010. Shift work, sleep, and sleepiness—differences between shift schedules and systems. Scand J Work Environ Health. 36(2):121–133. 10.5271/sjweh.2900

Sallinen M, Laukkanen-Nevala P, Olkinuora A, Puttonen S, Vanttola P, Virkkunen I 2018. Working hours, sleep and alertness in HEMS personnel in Finland. Lecture presented at: Biomedicum Helsinki, Helsinki, Finland.

Sivertsen B, Omvik S, Havik OE, Pallesen S, Bjorvatn B, Nielsen GH, Straume S, Nordhus IH. 2006. A comparison of actigraphy and polysomnography in older adults treated for chronic primary insomnia. Sleep. 29(10):1353–1358. doi:10.1093/sleep/29.10.1353

Smolensky MH, Portaluppi F, Manfredini R, Hermida RC, Tiseo R, Sackett-Lundeen LL, Haus EL 2015. Diurnal and twenty-four hour patterning of human diseases: cardiac, vascular, and respiratory diseases, conditions, and syndromes. Sleep Med Rev. 21(3–11). doi:10.1016/j.smrv.2014.07.001

Stone KL, Ancoli-Israel S. 2011. Actigraphy. In: Kryger MH, Roth T, Dement WC, editors. Principles and practice of sleep medicine. St. Louis, Missouri: Elsevier Saunders. p. 1668–1675.

Swanson LM, Arnedt JT, Rosekind MR, Belenky G, Balkin TJ, Drake C. 2011. Sleep disorders and work performance: findings from the 2008 national sleep foundation sleep in America poll. J Sleep Res. 20(3):487–494. doi:10.1111/j.1365-2869.2010.00890.x

Taylor CB, Stevenson M, Jan S, Liu B, Tall G, Middleton PM, Fitzharris M, Myburgh J. 2011. An investigation into the cost, coverage and activities of helicopter emergency medical services in the state of New South Wales, Australia. Injury. 42(10):1088–1094. doi:10.1016/j.injury.2011.02.013

Ursin R, Bjorvatn B, Holsten F. 2005. Sleep duration, subjective sleep need, and sleep habits of 40-to 45-year-olds in the Hordaland health study. Sleep. 28(10):1260–1269. 10.1093/sleep/28.10.1260

West BT, Welch KB, Galecki AT. 2014. Linear mixed models. 2nd ed ed. Arbor (MI): CRC Press.

Wuyts J, De Valck E, Vandekerckhove M, Pattyn N, Exadaktylos V, Haex B, Maes J, Verbraecken J, Cluydts R. 2012. Effects of pre-sleep simulated on-call instructions on subsequent sleep. Biol Psychol. 91(3):383–388. doi:10.1016/j.biopsycho.2012.09.003

Zakariassen E, Waage S, Harris A, Gatterbauer-Trischler P, Lang B, Voelckel W, Pallesen S, Bjorvatn B. 2019. Causes and management of sleepiness among pilots iN a Norwegian and an Austrian air ambulance service—a comparative study. Air Med J. 38(1):25–29. doi:10.1016/j.amj.2018.11.002

Ziebertz CM, Beckers DG, Van Hooff ML, Kompier MA, Geurts SA. 2017. The effect on sleep of being on-call: an experimental field study. J Sleep Res. 26(6):809–815. doi:10.1111/jsr.12519

International Journal of
Environmental Research and Public Health

Article

Sleep and Sleepiness Measured by Diaries and Actigraphy among Norwegian and Austrian Helicopter Emergency Medical Service (HEMS) Pilots

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Abstract: The study examined sleep and sleepiness among shift working Helicopter Emergency Medical Service pilots from Norway (Norwegian Air Ambulance; NAA) and Austria (Christophorus Flugrettungverein; CFV). Both pilot groups (N = 47) worked seven consecutive 24 h shifts. Sleep was assessed by diaries and actigraphy while sleepiness was assessed by the Karolinska Sleepiness Scale, all administered throughout the workweek. The results indicated that all pilots had later bedtime ($p < 0.05$) and wake-up time ($p < 0.01$) as they approached the workweek end, but no change during the workweek was evident regarding wake after sleep onset, time in bed, total sleep time, or sleep efficiency. The NAA pilots had later bedtime ($p < 0.001$) and wake-up time ($p < 0.001$), spent more time awake after sleep onset ($p < 0.001$), more time in bed ($p < 0.001$), slept longer ($p < 0.01$), and had lower sleep efficiency ($p < 0.001$) compared with the CFV pilots. The sleepiness levels of all pilots were slightly elevated on the first workday but lower on the following workdays ($^{\text{day 2}}$ $p < 0.001$, $^{\text{day 3}}$ $p < 0.05$). For both pilot groups, no major change in sleep or sleepiness parameters throughout the workweek was detected. The NAA pilots reported somewhat more disturbed sleep but obtained more sleep compared with the CFV pilots.

Keywords: sleep; sleepiness; shift work; long working hours; successive shifts; HEMS; air ambulance; somnolence; fatigue

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Citation: Flaa, T.A.; Bjorvatn, B.; Pallesen, S.; Zakariassen, E.; Harris, A.; Gatterbauer-Trischler, P.; Waage, S. Sleep and Sleepiness Measured by Diaries and Actigraphy among Norwegian and Austrian Helicopter Emergency Medical Service (HEMS) Pilots. *Int. J. Environ. Res. Public Health* **2022**, *19*, 4311. https://doi.org/10.3390/ijerph19074311

Academic Editor: Paul B. Tchounwou

Received: 3 March 2022
Accepted: 1 April 2022
Published: 4 April 2022

1. Introduction

Shift work is denoted as work that takes place at irregular hours, including evenings, nights, and weekends [1]. Long working hours represent one aspect of shift work and is often defined as work that exceeds 48 h per week [2]. Shift work and long working hours are associated with sleep loss, decreased job performance, and an increased rate of occupational accidents [3,4].

The Helicopter Emergency Medical Service (HEMS) represents a component of aviation whose primary function is to serve patients with severe disease or trauma, by providing rapid transport to hospital and/or transport of an anesthesiologist and HEMS crew members to the site [5,6]. HEMS is an on-demand service with an inherent urgency when missions occur. This entails taking on missions at any hour with potential challenging weather conditions, and operations are often conducted in rough and hostile terrains with an increased risk of accidents [7,8]. In Europe, the organization of HEMS varies in terms of scheduling and setting, ranging from 12 h shifts to seven consecutive 24 h shifts [9,10]. The Norwegian Air Ambulance (NAA) and the Christophorus Flugrettungverein (CFV) in Austria are two of few HEMS operators in Europe that share the same seven consecutive 24 h shift schedule, where the workers are stationed at the base during the workweek. However, the NAA operates 24/7 in contrast to the CFV that only takes on missions during daylight [10]. The latitude in Norway ranges from 58°03′ N to 70°66′ N while the Austrian latitude ranges from 46°53′ N to 48°82′ N.

The limited body of research that exists on sleep in HEMS shows ambiguous findings. As sleep loss and sleepiness are notable occupational hazards in aviation [11], more knowledge about sleep in HEMS is warranted. In terms of shift arrangement, one study suggested that a 7-day work period resulted in cumulative sleep loss of approximately 15 h [12], whereas another study found only 30 min of sleep debt following 24 h shifts [13]. An American study found poor sleep quality in 50% of the workers during 12 h and 24 h shifts. Nevertheless, they found no change in cognitive performance during the same shifts [14]. However, 84% of HEMS pilots working at least three consecutive 12 h day shifts reported that fatigue had affected their flight performance. Half of the pilots reported obtaining 4 h or more of sleep per day [15]. Previous findings for Norwegian HEMS crew revealed low sleepiness levels and a daily average of 7 h of sleep during workweeks. However, wake after sleep onset was longer and sleep efficiency was lower during the workweek, compared with weeks off work [16,17]. A comparative study indicated that there exist some differences between the NAA and CFV pilots regarding use of sleepiness strategies and elements that prevented napping at work. To prevent sleepiness, the NAA pilots napped and exercised, while the CFV pilots generally kept busy. Furthermore, the CFV pilots more frequently reported that environmental factors, phone calls, and administrative duties prevented napping [10].

Consequently, more research of sleep and sleepiness measures in relation to work hours in this occupational group is deemed necessary. A multicenter design provides a unique opportunity to gain insight into how the work setting and schedule affect the workers' sleep. Thus, the aim of the present study was to examine and compare sleep and sleepiness in HEMS pilots in two European countries working 24 h shifts for seven consecutive days. In addition, we examined whether the number and/or duration of missions affected sleep and sleepiness across the two pilot groups.

2. Materials and Methods

2.1. Participants

The study was conducted in Norway during the spring/summer of 2015 and in Austria during the spring/summer of 2016. For the present data collection, 29 pilots working on all nine Norwegian bases operated by the Norwegian Air Ambulance were invited to participate. Of these, 25 provided data that were eligible for analyses, yielding a response rate of 86%. A collaboration with the Austrian Christophorus Flugrettungverein was established in order to conduct a multicenter study on HEMS pilots with the same work schedule and using the same instruments. In Austria, 24 CFV pilots were invited to participate, comprising a representative sample of both rural and urban bases. Of these, 22 CFV pilots provided data that were eligible for inclusion, yielding a response rate of 92%.

2.2. Procedure

For the NAA pilots, the shift schedule comprised a 7 day work period followed by 14 days off work, then a new 7 day work period followed by 21 days off work. The workweek started and ended at 10:00 h on the first and seventh workday, respectively. The NAA takes on missions at all hours throughout the year. During the workweek, the pilots live together with the crew on a base that is fully equipped with all necessary facilities, including separate bedrooms with private bathrooms. For the CFV pilots, the shift schedule consisted of a 7-day work period followed by 7 days off work, then a new 7-day work period and 7 days off work. The workweek started at sunrise (06:00 h earliest) on the first workday and ended at sunset (21:00 h latest) on the seventh workday. The workers in Austria only perform missions initiated at daylight. During the workweek, the CFV pilots live together with the crew on a base, equipped with single bedrooms and enclosed private bathrooms. Those who live in proximity to the base (<30 min) have the option of spending the night at home. The fatigue risk management systems include flight and duty time limitations approved by the Civil Aviation Authority in Norway for NAA and the Austrian National Aviation Authority (Austro Control) for CFV (for details, see [10]).

2.3. Measures

2.3.1. Questionnaire

A questionnaire assessing demographic and background information was completed on the first workday. It included information regarding sex, age, years in position, caffeine intake at work (number of cups), sleep need (h), and the question "do you experience sleep problems related to your work schedule?" (1 = no to 5 = very much).

2.3.2. Mission Log

Both the NAA and CFV staff provided a daily overview of the number of missions and total time spent on missions for each worker. The total time spent on missions was recorded from the time an alarm initiated a mission until the workers landed back at base. As the NAA pilots also performed training sessions during the workweek, time spent on this activity was included in their data in order to calculate the total workload.

2.3.3. Sleep Diary

The sleep diary was completed upon awakening in the morning on all seven workdays. Sleep variables such as bedtime, wake-up time, wake after sleep onset, time in bed, total sleep time, and sleep efficiency (total sleep time/time in bed × 100) were calculated based on the diaries. In total, 45 out of 47 participants completed the sleep diary during the workweek.

2.3.4. Actigraphy

The workers wore an actigraph (Actiwatch 2, Respironics Inc., Cambridge, MA, USA), a device with the size and appearance of a watch, on the non-dominant wrist that records activity and movement continuously [18]. Based on these data, algorithms estimate sleep and wake profiles. The actigraphs recorded these individual profiles in 1 min epochs applying the default (medium) threshold for sleep/wake detection provided by the Actiware software. For the medium threshold, the number of activity counts used to identify wake (sensitivity threshold) was 40 counts per epoch, whereas the sleep start/end threshold was 10 min of inactivity/activity. The workers were instructed to wear the actigraph continuously throughout the workweek. The scoring was based on the steps proposed by Chow and colleagues [19], including a hierarchical approach first emphasizing event markers and activity levels. In the cases where the event marker was absent (35% of NAA observations/18% of CFV observations), sleep diary and activity levels were used to set sleep times. Bedtime, wake-up time, wake after sleep onset, time in bed, total sleep time, and sleep efficiency were calculated by the Actiware software. Due to technical problems, data from one actigraph was excluded from the analysis.

2.3.5. Karolinska Sleepiness Scale

Sleepiness was assessed by the Karolinska Sleepiness Scale (KSS) [20], which is a 9-point scale measuring subjective sleepiness (1 = very alert to 9 = very sleepy, great effort to stay awake, fighting sleep). Scoring seven or more indicates excessive sleepiness. The participants completed the KSS every other hour while awake throughout the workweek. Mean scores were extracted for the individual workday throughout the workweek but scores at every time point (every second hour awake between 08:00–00:00 during the workdays) were also noted. The KSS was completed by all 47 participants during the data collection period.

2.4. Data Analyses

Categorical variables are presented as numbers and percentages; *n* (%), whereas continuous variables are presented as mean (standard deviation [SD]) for symmetric data, and median (quartiles) for asymmetric data. The statistical analyses were conducted using Stata 16.1. Regarding the question about sleep problems related to the work schedule, none of the pilots ticked for the response options 'much' or 'very much'. The response alternatives 'very much', 'much', 'a little', and 'some' were merged into 'yes', and the variable was dichotomized into 'yes' and 'no' before conducting statistical analysis. Fisher's exact test was applied to examine differences between the countries in terms of sleep problems and sex, due to tables containing cells with a frequency <5 and a low sample size. Student's *t*-tests were applied to explore differences in age, sleep need, and caffeine intake, whereas Mann–Whitney U tests were used to compare differences in median values regarding years in position between the countries. The latter was also applied for analysis pertaining to the number and duration of missions. Linear mixed models (LMM) were used to analyze the sleep and sleepiness variables over the course of a workweek, both with NAA and CFV collapsed and separately for each crew. Specifically, the sleep variables bedtime, wake-up time, wake after sleep onset, time in bed, total sleep time, and sleep efficiency based both on sleep diaries and actigraphy were included as dependent variables. The KSS was fitted as the dependent variable for exploring sleepiness. Day (1–7) and time (only KSS; 08:00–00:00 h) were included in the models as a fixed factor with day 1 and 08:00 h as references, whereas subjects were included as a random factor in all analyses. Number of missions and time spent on missions were inserted as covariates. The statistical significance level was set at $p < 0.05$.

2.5. Missing Data

Both sleep diary data and KSS data were marked as missing if the worker failed to fill out certain time points or columns and when technical issues prevented data collection or extraction from the actigraphs. For all variables, the number of missing entries was not higher than 6%.

2.6. Ethics

The study protocol was reviewed and approved by the Regional Committee for Medical and Health Research Ethics, health region West, Norway (no. 2014/593). No additional ethical approval was needed by the corresponding Austrian authorities (415-EP/73/671-2016).

3. Results

3.1. Descriptive Statistics

Descriptive data are presented in Table 1.

Twenty-five NAA pilots (24 males/one female) and 22 CFV pilots (all males) participated in the study. The mean age was 43.6 (SD = 5.2) years for the NAA pilots and 42.8 (SD = 6.1) years for the CFV pilots. There was no significant age difference between the two crews (t = 0.457, p = 0.650). Similarly, no differences were evident between the pilot groups regarding sleep need (p = 0.225) or sleep problems related to work schedule (p = 0.144). However, the NAA pilots reported drinking more caffeinated beverages at work compared with the CFV pilots ($p < 0.01$), while the CFV pilots had more years in the same position compared with the NAA pilots ($p < 0.05$).

Table 1. Descriptive statistics of years in position, caffeine intake at work, sleep need, and sleep problems related to work schedule for pilots in The Norwegian Air Ambulance (NAA; $n = 25$) and Christophorus Flugrettungverein (CFV; $n = 22$).

	NAA	CFV	NAA	CFV	NAA	CFV		
	***n* (%)**		**Mean (SD)**		**Median (IQR)**		**Statistic**	***p*-Value**
Years in position ($n = 47$)					5 (3.5–7)	10.5 (5–15)	−2.18 [a]	0.029 [b]
Caffeine intake at work ($n = 45$)			4.58 (0.42)	3.05 (0.36)			2.73 [c]	0.009 [d]
0 cups	1 (4.0)	3 (13.6)						
1–2 cups	2 (8.0)	3 (13.6)						
3–4 cups	7 (28.0)	11 (50.0)						
5–6 cups	10 (40.0)	4 (18.2)						
>7 cups	5 (20.0)	1 (4.6)						
Sleep need [§] ($n = 44$)			07:01 (00:40)	07:16 (00:38)			−1.23 [c]	0.225 [d]
Sleep problems related to work schedule ($n = 45$)								0.231 [e]
Yes	7 (28.0)	11 (50.0)						
No	18 (72.0)	11 (50.0)						

[§] hh:mm, [a] z value, [b] *p*-value based on Mann–Whitney U, [c] *t*-value, and [d] *p*-value based on Student's *t*-test, [e] *p*-value based on Fisher's exact test.

3.2. Number of Missions and Time Spent on Missions

For the NAA pilots, the median (quartiles) number of missions during the workweek was 19 (13–22), ranging from 7–30, whereas the corresponding numbers for the CFV pilots were 26 (21–30), ranging from 15–51, which amounted to a significant difference in the pilot groups ($z = -3.25$, $p < 0.01$). In total, 42 (9%) of the NAA pilots' missions were classified as night missions (between 00:00–07:00 h). For the NAA pilots, the median (quartiles) time spent on missions during the workweek was 23.3 h (19.1–32.9), ranging from 13.2–48.0, and 23.7 h (19.4–29.5), ranging from 15.4–58.3, for CFV pilots, however, this difference was not significant ($z = -0.023$, $p = 0.981$).

3.3. Sleep Measured throughout the Workweek

Sleep diary and actigraphy data are presented in Tables 2 and 3 and Figures 1–5.

Table 2. Unstandardized beta coefficients for sleep variables in pilots from the Norwegian Air Ambulance (NAA; $n = 25$) and Christophorus Flugrettungverein (CFV; $n = 22$) during a workweek, derived from sleep diary and actigraphy.

	Sleep Diary																	
	Bedtime			**Wake-Up Time**			**Wake after Sleep Onset**			**Time in Bed**			**Total Sleep Time**			**Sleep Efficiency**		
	Both	**NAA**	**CFV**	**Both**	**NAA**	**CFV**	**Both**	**NAA**	**CFV**	**Both**	**NAA**	**CFV**	**Both**	**NAA**	**CFV**	**Both**	**NAA**	**CFV**
Day																		
1 §																		
2	0.043	0.115	−0.056	−0.021	−0.092	−0.008	0.170	0.365	0.007	−0.086	−0.238	0.054	−0.255	−0.707	0.126	−2.18	−6.50	1.31
3	−0.267	−0.412	−0.149	−0.002	−0.077	−0.021	0.065	0.177	0.001	0.273	0.322	0.187	0.215	0.099	0.201	−0.471	−2.65	0.383
4	−0.036	0.087	−0.188	0.218	0.352	0.049	0.049	0.134	−0.021	0.288	0.317	0.255	0.257	0.122	0.369	0.109	−2.11	1.93
5	0.196	0.467	−0.118	0.223	0.328	0.025	0.024	0.084	0.010	0.049	−0.101	0.174	−0.032	−0.364	0.196	−1.06	−3.42	0.126
6	0.347	0.464	0.142	0.451	0.673	0.168	0.099	0.238	−0.006	0.113	0.253	0.027	0.084	0.032	0.154	0.261	−2.20	2.06
7	0.524 *	0.364	0.638 *	0.644 **	−0.519	1.80 ***	−0.094	−0.154	−0.001	0.232	−0.875 *	1.40 ***	0.213	−0.858 *	1.31 ***	−0.900	−2.55	0.115
	Actigraphy																	
	Bedtime			Wake-up time			Wake after sleep onset			Time in bed			Total sleep time			Sleep efficiency		
	Both	NAA	CFV	Both	NAA	CFV	Both	NAA	CFV	Both	NAA	CFV	Both	NAA	CFV	Both	NAA	CFV
Day																		
1 §																		
2	0.287	0.304	0.288	0.135	0.246	0.036	0.211	0.361	0.075	−0.148	−0.032	−0.255	−0.249	−0.352	−0.183	−1.78	−3.94	0.264
3	−0.089	−0.429	0.311	−0.110	−0.092	−0.098	0.032	0.080	0.024	−0.010	0.363	−0.409	0.038	0.276	−0.319	0.485	0.100	0.331
4	0.084	0.215	−0.050	0.148	0.435	−0.145	0.132	0.210	0.034	0.069	0.244	−0.097	0.007	0.073	−0.034	−0.888	−1.84	0.246
5	0.257	0.583 *	−0.052	0.522	1.01 **	0.022	0.086	0.141	0.057	0.274	0.457	0.073	0.322	0.443	0.110	0.802	0.954	0.193
6	0.564 **	0.801 **	0.307	0.685 *	1.36 **	−0.001	0.219	0.397	−0.014	0.132	0.627	−0.314	−0.012	0.281	−0.182	−1.30	−2.38	0.467
7	0.555 **	0.098	1.02 ***	0.539 *	−0.960 *	2.05 ***	−0.020	−0.197	0.142 *	−0.011	−1.02 *	1.03 ***	0.051	−0.861 *	1.00 **	−0.428	−0.717	0.084

* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$. § Represents the reference groups. The 'both' category refers to both pilot groups collapsed.

Table 3. The effect of missions on sleep variables in pilots from the Norwegian Air Ambulance (NAA; n = 25) and Christophorus Flugrettungverein (CFV; n = 22), derived from sleep diary and actigraphy, reported in unstandardized beta coefficients.

	Sleep Diary											
	Bedtime		**Wake-Up Time**		**Wake after Sleep Onset**		**Time in Bed**		**Total Sleep Time**		**Sleep Efficiency**	
	NAA	**CFV**	**NAA**	**CFV**	**NAA**	**CFV**	**NAA**	**CFV**	**NAA**	**CFV**	**NAA**	**CFV**
Number §	−0.061	−0.052	−0.126	0.006	0.073	0.002	−0.048	0.023	−0.158	0.062	−1.26	0.540
Duration ∫	0.003 ***	0.002 *	0.003 **	0.001	−0.001 *	−0.000	−0.000	−0.001	0.002	−0.001	0.023 **	−0.005
	Actigraphy											
	Bedtime		Wake-up time		Wake after sleep onset		Time in bed		Total sleep time		Sleep efficiency	
	NAA	CFV	NAA	CFV	NAA	CFV	NAA	CFV	NAA	CFV	NAA	CFV
Number §	0.017	−0.050	−0.010	−0.032	0.093	−0.019	−0.020	0.017	−0.154	0.083	−1.03	0.187 *
Duration ∫	0.002 **	0.002 **	0.002	0.002 *	−0.001	−0.000	−0.001	−0.001	0.001	−0.001	0.008	−0.001

* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$. § Number of missions. ∫ Duration of missions.

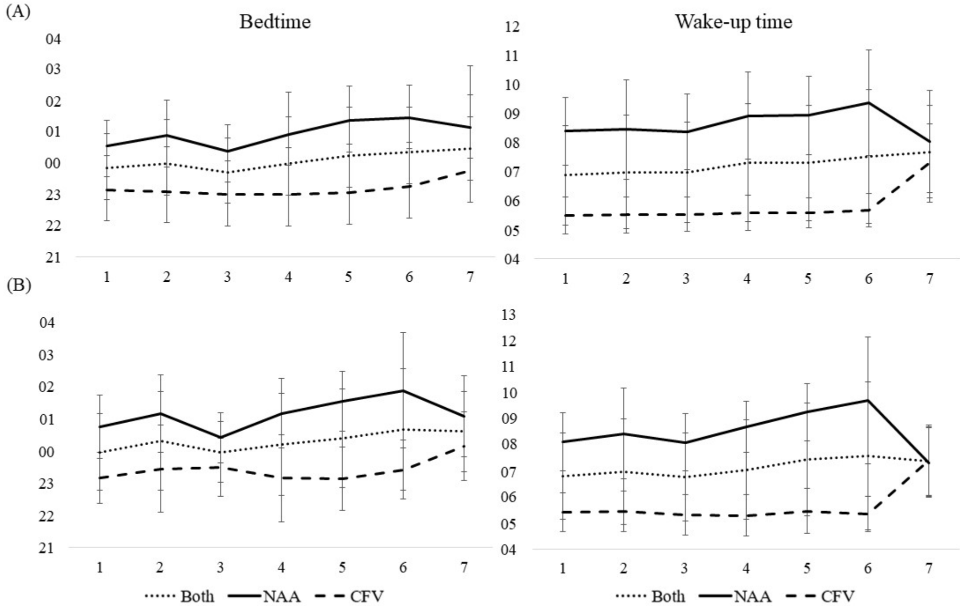

Figure 1. Mean scores of bedtime and wake-up time during a 7-day workweek among pilots in the Norwegian Air Ambulance (NAA; n = 25), Christophorus Flugrettungverein (CFV; n = 22), and both groups collapsed, measured by (**A**) sleep diary and (**B**) actigraphy. Error bars represent standard deviations.

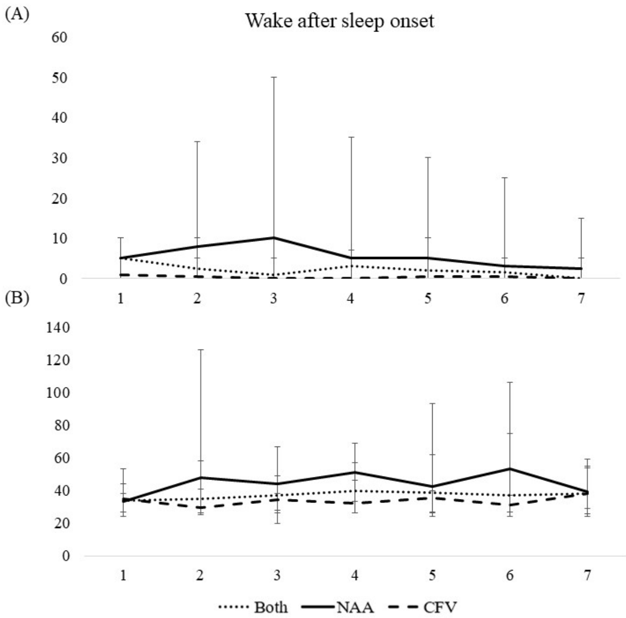

Figure 2. Median scores of wake after sleep onset during a 7-day workweek among pilots in the Norwegian Air Ambulance (NAA; n = 25), Christophorus Flugrettungverein (CFV; n = 22), and both groups collapsed, measured by (**A**) sleep diary and (**B**) actigraphy. Error bars represent quartiles.

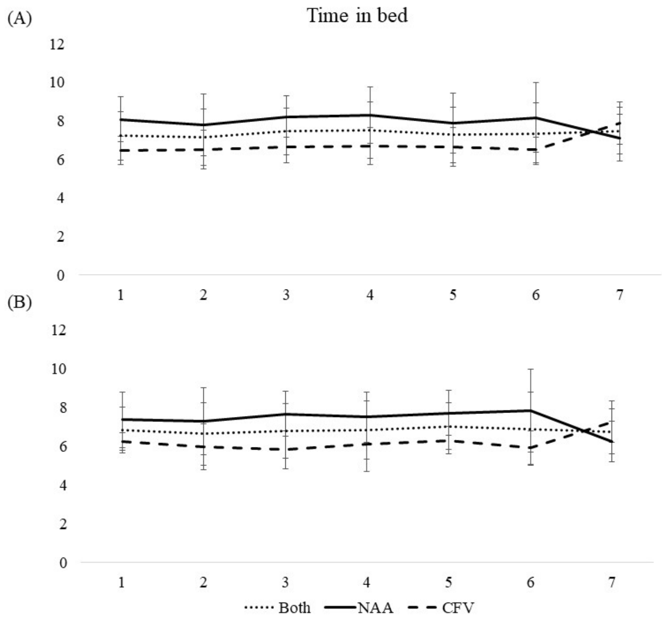

Figure 3. Mean scores of time in bed during a 7-day workweek among pilots in the Norwegian Air Ambulance (NAA; $n = 25$), Christophorus Flugrettungverein (CFV; $n = 22$), and both groups collapsed, measured by (**A**) sleep diary and (**B**) actigraphy. Error bars represent standard deviations.

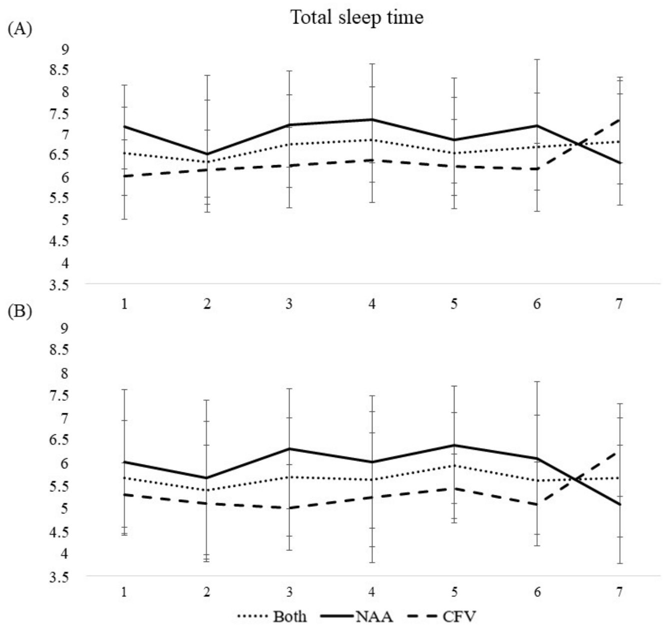

Figure 4. Mean scores of total sleep time during a 7-day workweek among pilots in the Norwegian Air Ambulance (NAA; $n = 25$), Christophorus Flugrettungverein (CFV; $n = 22$), and both groups collapsed, measured by (**A**) sleep diary and (**B**) actigraphy. Error bars represent standard deviation.

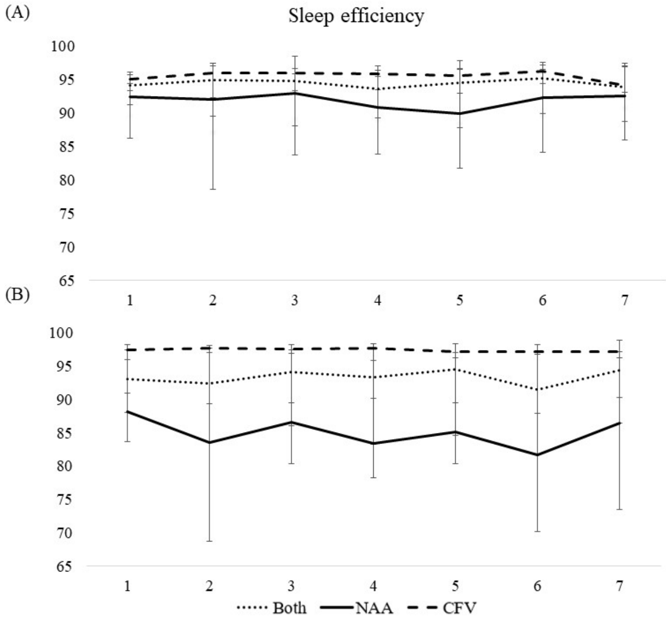

Figure 5. Median scores of sleep efficiency during a 7-day workweek among pilots in the Norwegian Air Ambulance (NAA; n = 25), Christophorus Flugrettungverein (CFV; n = 22), and both groups collapsed, measured by (**A**) sleep diary and (**B**) actigraphy. Error bars represent quartiles.

3.3.1. Bedtime and Wake-Up Time

For both pilot groups collapsed, bedtime and wake-up time measured with sleep diaries were consistent throughout the workweek, except for day 7 which had later bedtime and wake-up time compared with the reference day (day 1) (Table 2, Figure 1). Bedtime and wake-up time measured with actigraphy revealed a consistency the first five days, followed by later bedtime and wake-up time on day 6 and 7 compared with the reference day (Table 2, Figure 1). A difference between the pilot groups was evident, where NAA pilots had later bedtime ($^{\text{diary NAA}}$00:57 h vs. $^{\text{CFV}}$23:10 h, $b = -1.67$, $p < 0.001$, $^{\text{actigraphy NAA}}$01:09 h vs. $^{\text{CFV}}$23:26 h, $b = -1.73$, $p < 0.001$) and wake-up time ($^{\text{diary NAA}}$08:38 h vs. $^{\text{CFV}}$05:47 h, $b = -2.73$, $p < 0.001$, $^{\text{actigraphy NAA}}$08:32 h vs. $^{\text{CFV}}$05:40 h, $b = -2.85$, $p < 0.001$) compared with the CFV pilots.

For the NAA pilots, there was no change in bedtime or wake-up time throughout the workweek as measured with the sleep diary. Bedtime and wake-up time measured with actigraphy revealed a consistency the first four days of the workweek, but were later on day 5 and 6, whereas wake-up time was earlier on day 7 compared with the reference day (Table 2, Figure 1). The number of missions neither affected bedtime or wake-up time, but the duration of missions was positively associated with later bedtime (assessed with both sleep diary and actigraphy) and wake-up time (sleep diary) (Table 3). For the CFV pilots, no change in bedtime and wake-up time throughout the workweek was evident, except for day 7 which was delayed compared with the reference day (Table 2, Figure 1). The number of missions did not affect bedtime or wake-up time. The duration of missions was positively associated with later bedtime (sleep diary and actigraphy) and wake-up time (actigraphy) (Table 3).

3.3.2. Wake after Sleep Onset, Time in Bed, Total Sleep Time, and Sleep Efficiency

Wake after sleep onset, time in bed, total sleep time, and sleep efficiency were all consistent throughout the workweek for both pilot groups collapsed (Table 2, Figures 2–5). A difference between the pilot groups was evident, where the NAA pilots spent more time awake after sleep onset ($^{\text{diary NAA}}$00:05 h vs. $^{\text{CFV}}$00:00 h, b = -.417, $p < 0.001$, $^{\text{actigraphy NAA}}$00:43 h vs. $^{\text{CFV}}$00:34 h, $b = -0.498$, $p < 0.001$), more time in bed ($^{\text{diary NAA}}$07:56 h vs. $^{\text{CFV}}$06:45 h, $b = -1.17$, $p < 0.001$, $^{\text{actigraphy NAA}}$07:23 h vs. $^{\text{CFV}}$06:14 h, $b = -1.12$, $p < 0.001$), slept longer ($^{\text{diary NAA}}$06:58 h vs. $^{\text{CFV}}$06:22 h, $b = -0.508$, $p < 0.01$, $^{\text{actigraphy NAA}}$05:58 h vs. $^{\text{CFV}}$05:22 h, $b = -0.670$, $p < 0.01$), and had lower sleep efficiency ($^{\text{diary NAA}}$91.7% vs. $^{\text{CFV}}$95.6%, $b = 7.29$, $p < 0.001$, $^{\text{actigraphy NAA}}$85.4% vs. $^{\text{CFV}}$97.3%, $b = 17.0$, $p < 0.001$) compared with the CFV pilots. For the NAA pilots, no change in wake after sleep onset or sleep efficiency was evident throughout the workweek. Time in bed and total sleep time were consistent throughout the workweek, except for day 7 where the scores were lower compared with the reference day (Table 2). The number of missions neither affected wake after sleep onset or sleep efficiency, however, the duration of missions was negatively associated with wake after sleep onset (sleep diary) and positively associated with sleep efficiency (sleep diary). Neither number of missions or duration of missions affected time in bed and total sleep time (Table 3).

For the CFV pilots, no changes in wake after sleep onset or sleep efficiency were evident throughout the workweek. Time in bed and total sleep time were consistent throughout the workweek, except for day 7 where the scores were higher compared with the reference day (Table 2, Figures 2–5). Number of missions was positively associated with sleep efficiency (actigraphy), but not related to wake after sleep onset, time in bed, or total sleep time. Duration of missions neither affected wake after sleep onset, time in bed, total sleep time or sleep efficiency irrespective of instrument used (Table 3).

3.4. Sleepiness Measured throughout the Workweek

Karolinska Sleepiness Scale (KSS)

Results regarding sleepiness are presented in Table 4 and Figure 6.

Table 4. Unstandardized beta coefficients for Karolinska Sleepiness Scale scores throughout the workweek (7 days) and during workdays (08:00–00:00) in pilots from the Norwegian Air Ambulance (NAA; $n = 25$) and Christophorus Flugrettungverein (CFV; $n = 22$).

	Both	**NAA**	**CFV**
Day			
1 §			
2	−0.452 ***	−0.732 ***	−0.126
3	−0.313 *	−0.435	−0.177
4	−0.374	−0.683 *	0.018
5	−0.459	−0.757	−0.103
6	−0.474	−0.690	−0.093
7	−0.439	−0.634	−0.143
Time			
08 §			
10	−0.274 *	−0.662 ***	−0.213
12	−0.369 **	−0.943***	−0.159
14	−0.166	−0.885 ***	0.195
16	0.094	−0.656 ***	0.485 ***
18	0.221 *	−0.399 *	0.469 ***
20	0.350 **	−0.581 **	0.943 ***
22	1.18 ***	0.006	2.11 ***
00	2.08 ***	1.16 ***	3.35 ***

* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$. § Represents the reference groups. The 'both' category refers to both pilot groups collapsed.

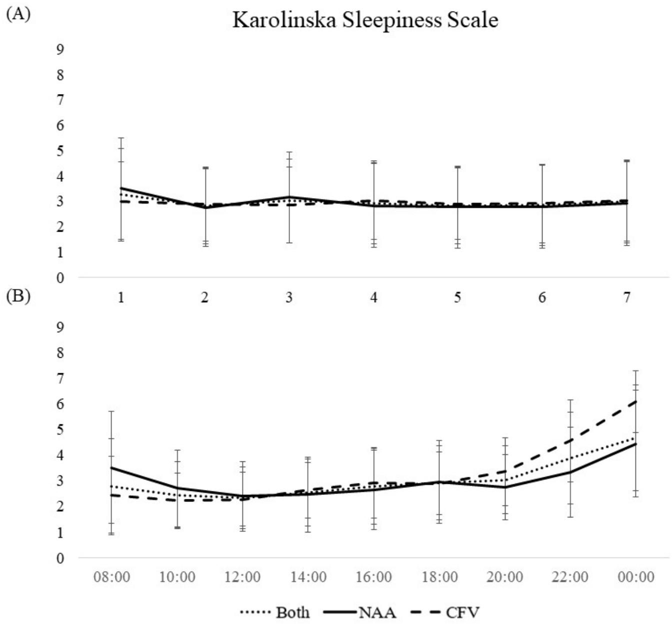

Figure 6. Mean scores of Karolinska Sleepiness Scale among pilots in the Norwegian Air Ambulance (NAA; $n = 25$), Christophorus Flugrettungverein (CFV; $n = 22$), and both groups collapsed. (**A**) During a 7-day workweek and (**B**) between 08:00–00:00 on workdays. Error bars represent standard deviation.

For both pilot groups collapsed, day 2 ($p < 0.001$) and day 3 ($p < 0.05$) had lower KSS scores compared with the reference day (day 1) during the workweek. For time of day, the KSS scores at 10:00 ($p < 0.05$) and 12:00 ($p < 0.01$) were lower, while the scores at 18:00 ($p < 0.05$), 20:00 ($p < 0.01$), 22:00 ($p < 0.001$), and 00:00 ($p < 0.001$) were higher compared with the reference time (08:00 h). No difference between the pilot groups was evident ($b = -0.039$, $p = 0.814$).

4. Discussion

The results for both pilot groups collapsed indicated a slight delay in the sleep period towards the end of the workweek. No change throughout the workweek was evident for wake after sleep onset, time in bed, total sleep time, or sleep efficiency. However, several differences between the HEMS contingent on country were present. The NAA pilots had nearly two hours later bedtime and nearly three hours later wake-up time, they spent over an hour more in bed, slept about 40 min more, and had lower sleep efficiency compared with the CFV pilots (on sleep diaries). The sleepiness scores for both pilot groups collapsed were overall low throughout the workweek but were slightly elevated on the first workday compared with the rest of the workweek. Not surprisingly, over the course of a day, the sleepiness levels comprised a slight U-curve including a steady increase towards the end of the day.

The results indicated that bedtime and wake-up times were consistent in the beginning of the workweek and then somewhat delayed towards the last days of the workweek. This delay could be explained by protection from domestic obligations that relieve the pilots of duties involving early wake-up times (i.e., child rearing and/or transportation to work/kindergarten/school). However, one should keep in mind that those CFV pilots who lived less than 30 min from the base could spend their nights at home during the workweek. Furthermore, missions occurring at late hours may delay bedtime, and especially, combined with the absence of early morning missions could explain these findings. However, we do not have detailed information about when the missions occurred, thus more studies are needed to clarify this.

The NAA pilots had clearly later bedtime and wake-up times compared with the CFV pilots. While the CFV pilots only initiated missions during daylight, the NAA pilots also took on missions after dark, which could explain why they went to bed and woke up later than the CFV pilots as night work is known to delay the circadian rhythm [21]. Latitude and daylight exposure could also influence the findings. For example, the average hours of daylight in May in Oslo is 17:14 h compared with 15:16 h in Vienna [22,23]. The difference between the NAA and CFV pilots' latitude location could therefore at least partly explain these aforementioned effects. The higher number of missions for the CFV pilots could explain earlier wake-up times compared with the NAA pilots. Subsequently, CFV pilots who spent the night at home would have to get up even earlier to reach base before dawn which could contribute further to this discrepancy. The bedtime and wake-up time were positively associated with the duration of missions for both groups. This could indicate that the more time the pilots spent on missions, the more delayed their sleep period would be. This notion is in accordance with a previous HEMS study in Norway, where higher amounts of total work time were associated with later bedtime during the summer season [16].

Time in bed and total sleep time obtained by both pilot groups collapsed were consistent throughout the workweek. Furthermore, the NAA pilots spent more time in bed and had higher total sleep time (close to 7 h per night) compared with the CFV pilots (about 6.5 h per night). As all NAA pilots live on the base during their workweek, this could enable them to spend more time in bed and thus obtain more total sleep time despite also spending more time awake after sleep onset than the CFV pilots. However, there are some uncertainties related to what extent the CFV pilots spend their nights at home as this was not registered.

The self-reported sleep need was 07:01 h for the NAA pilots and 07:16 h for the CFV pilots. The results concerning total sleep time measured with sleep diaries indicated that the NAA pilots obtained approximately the self-reported need, while the CFV pilots obtained less. Total sleep time derived from actigraphy was clearly lower than that measured by the sleep diary, which is a common finding in studies using both instruments [24,25]. Still, the diary findings indicated that most of the pilots obtained the recommended or, at least, appropriate amounts of sleep according to Hirshkowitz and colleagues [26]. This is contrary to other studies that have reported restricted sleep duration when working irregular shifts and long hours [25,27]. However, the discrepancy between the two sleep measures necessitates a cautious interpretation of the results and should be considered in the development of the internal fatigue risk management systems.

The wake after sleep onset and sleep efficiency were consistent throughout the week for both pilot groups collapsed. Furthermore, the NAA pilots spent more time awake after sleep onset and had lower sleep efficiency compared with the CFV pilots. As previously mentioned, the NAA pilots conduct missions after dark, while the CFV pilots do not. Although only 9% of their missions were classified as night missions, this could still explain the greater amount of time spent awake after sleep onset and thus lower sleep efficiency. Additionally, the NAA pilots could receive calls and mission assessments, not resulting in missions, but that required the pilots to wake up. However, detailed data on calls and mission assessments were not available, hence the aforementioned notions are somewhat speculative. Nevertheless, on-call studies have found longer wake time after sleep onset and lower sleep efficiency during on-call nights, even when calls were absent [28–30]. This suggests that the mere anticipation of a call or mission could lead to more wakefulness. Hence, both actual and anticipated missions during the sleep period could result in longer wake time after sleep onset and lower sleep efficiency for the NAA pilots.

Interestingly, results for the two pilot groups revealed a convergence on the last workday, where the NAA pilots woke up earlier, spent less time in bed, and had lower total sleep time, whereas the CFV pilots woke up later, spent more time in bed, and had higher total sleep time compared with the previous workdays. The changes in the NAA pilots' sleep variables could be due to tasks and duties that had to be completed upon the end of the workweek and may also reflect that they lived farther from the base than the CFV pilots and hence had more strenuous travel arrangements ahead. However, one might also expect similar tasks and duties for the CFV pilots, but the opposite finding complicates the interpretation.

The overall sleepiness levels were low throughout the workweek for both pilot groups. As both pilot groups primarily live on the base during the workweek, the base facilities including separate bedrooms could promote good rest in between missions, resulting in low sleepiness levels. This is contrary to previous findings on sleepiness and shift work [31,32]. A study on pilots found, for example, faster accumulation of fatigue in multi-segmented workdays compared with single segmented [33]. Although the CFV pilots conducted more missions than the NAA pilots, there was no difference between the countries regarding sleepiness scores. This may suggest that living on base during the workweek protected against domestic responsibilities that otherwise could cause an increase in sleepiness. This notion was supported by a study that found that 26% of HEMS pilots reported sleep disturbance due to child care [15]. The sleepiness levels were slightly increased on the first workday but remained low on the remaining workdays for all pilots. This could be due to the commute on the first workday, as the workweek started at 10:00 h and at sunrise (earliest 06:00 h) for the NAA and CFV pilots, respectively. Considerable commute time would imply an early morning for the pilots in order to reach the base for shift start. Over the course of a workday, the sleepiness levels were low at the start with an increase towards the end. Rather than being a consequence of the work schedule and setting, this variation in sleepiness resembled the oscillations of normal circadian rhythms [34]. The results on sleepiness corroborate a previous Norwegian HEMS study where both pilots (the same pilots as in the present study) and HEMS crew members reported low sleepiness levels throughout the workweek and over the course of a workday. Interestingly, this previous study also found the sleepiness levels during the workweek to be lower than the weeks off (both preceding and following) work [17]. A recent review found that risk associated with fatigue increases as the workdays exceeds 16 h and coincides with habitual sleep hours [35]. The current sleepiness results indicated that neither the NAA nor the CFV pilots experienced substantial sleepiness throughout the workweek or workdays although the work setting included more than 16 h workdays and work in conflict with habitual sleep hours.

Some strengths and limitations of the present study should be noted. The multicenter and longitudinal design with numerous daily measurements over seven consecutive days provided detailed insight into the oscillation of sleep and sleepiness during the workweek in two different countries with similar shift schedules. This intensive data collection diminished the chance of recollection bias and improve data quality. The study included both subjective and objective measurements which also represent an asset, as it enables thorough documentation of the pilots' sleep. The objective sleep measures prevent data from being influenced by response biases associated with subjective measures.

The "healthy worker effect" could have influenced our results, as the pilots represent a highly selected and resilient cohort that cope well with the shift schedule and work setting. For this reason, generalizing to other work populations must be conducted with prudence. However, as this occupation constitutes a high-risk operation for pilots, HEMS crew members, and patients, information about how this particular groups' sleep is affected by the work schedule is of high value. Some discrepancies between sleep diary and actigraphy data were noted and are in line with previous studies [24,36] reflecting different (self-report and movement) data sources. Furthermore, as the HEMS is a male-dominant occupation, the sample expectedly consisted predominantly of males. Thus, generalization of the findings to other populations with a higher proportion of females must be made with caution. The mission data could benefit from a higher level of detail (timing, type, etc.) that would enable a more comprehensive analyses of their impact on sleep and sleepiness. Future studies should include larger sample sizes (i.e., several pilot groups) and several workweeks per pilot in order to generate mission data quantities that enable more sophisticated analyses. Furthermore, future studies would benefit from including objective measures of sleepiness, such as the Multiple Sleep Latency Test (MSLT) [37]. However, the MSLT may be somewhat challenging to conduct in field studies such as the present. Other tests of sleepiness, such as the alpha attenuation test [38], may be more suitable in the field.

Although no major sleep problems were detected among the pilots in the present study, the importance of maintaining good sleep for workers in this occupational group should be emphasized. By utilizing sleep opportunities and maintaining a consistent bed- and rise time that aligns with the circadian rhythm, when possible, the workers may be better prepared to meet the unpredictable workload and workhours comprised by the work setting. Furthermore, fatigue risk management systems should be under continuous development to ensure that the potential negative effects of the shift schedule are attenuated. Specific alertness management programs [39] could be one approach to increase awareness and improve alertness strategies among pilots.

5. Conclusions

No substantial changes in sleep or sleepiness parameters throughout the workweek were evident. Differences between the two pilot groups were detected, where the NAA pilots reported more fragmented sleep than the CFV pilots. These differences could be due to missions conducted after daylight by the NAA pilots. Still, both pilot groups reported on average more than 6 h of subjective sleep throughout the workweek which lasted 24 h over 7 consecutive days. This could indicate that the pilots cope well with the shift schedule despite its known risk factors (i.e., night work). Fatigue risk management strategies should nevertheless continue to evolve and tailor mitigating measures to avoid the potential detrimental effects.

Author Contributions: S.W., E.Z., B.B., S.P. and A.H. conceived and designed the study; S.W. and E.Z. conducted the data collection in Norway, and P.G.-T. in Austria. T.A.F. analyzed the data and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: The research project was financially supported by a grant from the Norwegian Air Ambulance Foundation.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Regional Committee for Medical and Health Research Ethics Western Norway (project code 2014/593, approved 22 May 2014). No additional ethical approval was needed by the corresponding Austrian authorities (415-EP/73/671-2016).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are available upon reasonable request.

Acknowledgments: We thank the NAA and CFV, including all their pilots, for participating in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. European Parliament, Council of the European Union. Directive 2003/88/EC of the European parliament and of the council of 4 November 2003 concerning certain aspects of the organisation of working time. *Off. J. Eur. Union.* **2003**, *L299*, 9–11. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32003L0088 (accessed on 9 February 2021).
2. Harrington, J.M. Health effects of shift work and extended hours of work. *Occup. Environ. Med.* **2001**, *58*, 68–72. [CrossRef]
3. Fischer, D.; Lombardi, D.A.; Folkard, S.; Willetts, J.; Christiani, D.C. Updating the "Risk Index": A systematic review and meta-analysis of occupational injuries and work schedule characteristics. *Chronobiol. Int.* **2017**, *34*, 1423–1438. [CrossRef] [PubMed]
4. Kecklund, G.; Axelsson, J. Health consequences of shift work and insufficient sleep. *BMJ* **2016**, *355*, i5210. [CrossRef]
5. Hankins, D.G. Air medical transport of trauma patients. *Prehosp. Emerg. Care* **2006**, *10*, 324–327. [CrossRef]
6. Sollid, S.J.M.; Rehn, M. The role of the anaesthesiologist in air ambulance medicine. *Curr. Opin. Anaesthesiol.* **2017**, *30*, 513–517. [CrossRef]

7. Blumen, I. *UCAN Safety Committee. A Safety Review and Risk Assessment in Air Medical Transport: Supplement to the Air Medical Physician Handbook*; Air Medical Physician Association: Salt Lake City, UT, USA, 2002.
8. Butler, B. Helicopter emergency medical services and weather-related accidents. *Air Med. J.* **2014**, *33*, 84–85. [CrossRef]
9. Radstaak, M.; Geurts, S.A.E.; Beckers, D.G.J.; Brosschot, J.F.; Kompier, M.A.J. Recovery and well-being among Helicopter Emergency Medical Service (HEMS) pilots. *Appl. Ergon.* **2014**, *45*, 986–993. [CrossRef]
10. Zakariassen, E.; Waage, S.; Harris, A.; Gatterbauer-Trischler, P.; Lang, B.; Voelckel, W.; Pallesen, S.; Bjorvatn, B. Causes and management of sleepiness among pilots in a Norwegian and an Austrian air ambulance service—A comparative study. *Air Med. J.* **2019**, *38*, 25–29. [CrossRef]
11. Sallinen, M.; Sihvola, M.; Puttonen, S.; Ketola, K.; Tuori, A.; Härmä, M.; Kecklund, G.; Åkerstedt, T. Sleep, alertness and alertness management among commercial airline pilots on short-haul and long-haul flights. *Accid. Anal. Prev.* **2017**, *98*, 320–329. [CrossRef]
12. Samel, A.; Vejvoda, M.; Maass, H. Sleep deficit and stress hormones in helicopter pilots on 7-day duty for emergency medical services. *Aviat. Space Environ. Med.* **2004**, *75*, 935. [PubMed]
13. Frakes, M.; Kelly, J. Sleep debt and outside employment patterns in helicopter air medical staff working 24-hour shifts. *Air Med. J.* **2007**, *26*, 45–49. [CrossRef] [PubMed]
14. Guyette, F.X.; Morley, J.L.; Weaver, M.D.; Patterson, P.D.; Hostler, D. The effect of shift length on fatigue and cognitive performance in air medical providers. *Prehosp. Emerg. Care* **2013**, *17*, 23–28. [CrossRef] [PubMed]
15. Gregory, K.B.; Winn, W.; Johnson, K.; Rosekind, M.R. Pilot fatigue survey: Exploring fatigue factors in air medical operations. *Air Med. J.* **2010**, *29*, 309–319. [CrossRef]
16. Flaa, T.A.; Bjorvatn, B.; Pallesen, S.; Røislien, J.; Zakariassen, E.; Harris, A.; Waage, S. Subjective and objective sleep among air ambulance personnel. *Chronobiol. Int.* **2021**, *38*, 129–139. [CrossRef]
17. Flaa, T.A.; Harris, A.; Bjorvatn, B.; Gundersen, H.; Zakariassen, E.; Pallesen, S.; Waage, S. Sleepiness among personnel in the Norwegian Air Ambulance Service. *Int. Arch. Occup. Environ. Health* **2019**, *92*, 1121–1130. [CrossRef]
18. CamNTech Ltd. Available online: https://www.camntech.com/ (accessed on 10 December 2021).
19. Chow, C.M.; Wong, S.N.; Shin, M.; Maddox, R.G.; Feilds, K.-L.; Paxton, K.; Steinbeck, K. Defining the rest interval associated with the main sleep period in actigraph scoring. *Nat. Sci. Sleep* **2016**, *8*, 321. [CrossRef]
20. Akerstedt, T.; Gillberg, M. Subjective and objective sleepiness in the active individual. *Int. J. Neurosci.* **1990**, *52*, 29–37. [CrossRef]
21. Sunde, E.; Mrdalj, J.; Pedersen, T.; Thun, E.; Bjorvatn, B.; Grønli, J.; Harris, A.; Waage, S.; Pallesen, S. Role of nocturnal light intensity on adaptation to three consecutive night shifts: A counterbalanced crossover study. *Occup Env. Med* **2020**, *77*, 249–255. [CrossRef]
22. Worlddata. Sunrise and Sunset in Austria. Available online: https://www.worlddata.info/europe/austria/sunset.php (accessed on 10 December 2021).
23. Worlddata. Sunrise and Sunset in Norway. Available online: https://www.worlddata.info/europe/norway/sunset.php (accessed on 10 December 2021).
24. Curtis, A.F.; Miller, M.B.; Boissoneault, J.; Robinson, M.; Staud, R.; Berry, R.B.; McCrae, C.S. Discrepancies in sleep diary and actigraphy assessments in adults with fibromyalgia: Associations with opioid dose and age. *J. Sleep Res.* **2019**, *28*, e12746. [CrossRef]
25. Ganesan, S.; Magee, M.; Stone, J.E.; Mulhall, M.D.; Collins, A.; Howard, M.E.; Lockley, S.W.; Rajaratnam, S.M.; Sletten, T.L. The impact of shift work on sleep, alertness and performance in healthcare workers. *Sci. Rep.* **2019**, *9*, 4635. [CrossRef] [PubMed]
26. Hirshkowitz, M.; Whiton, K.; Albert, S.M.; Alessi, C.; Bruni, O.; DonCarlos, L.; Hazen, N.; Herman, J.; Katz, E.S.; Kheirandish-Gozal, L.; et al. National Sleep Foundation's sleep time duration recommendations: Methodology and results summary. *Sleep Health* **2015**, *1*, 40–43. [CrossRef] [PubMed]
27. Swanson, L.M.; Arnedt, J.T.; Rosekind, M.R.; Belenky, G.; Balkin, T.J.; Drake, C. Sleep disorders and work performance: Findings from the 2008 National Sleep Foundation Sleep in America poll. *J. Sleep Res.* **2011**, *20*, 487–494. [CrossRef] [PubMed]
28. Sprajcer, M.; Jay, S.M.; Vincent, G.E.; Vakulin, A.; Lack, L.; Ferguson, S.A. How the chance of missing the alarm during an on-call shift affects pre-bed anxiety, sleep and next day cognitive performance. *Biol. Psychol.* **2018**, *137*, 133–139. [CrossRef]
29. Wuyts, J.; De Valck, E.; Vandekerckhove, M.; Pattyn, N.; Exadaktylos, V.; Haex, B.; Maes, J.; Verbraecken, J.; Cluydts, R. Effects of pre-sleep simulated on-call instructions on subsequent sleep. *Biol. Psychol.* **2012**, *91*, 383–388. [CrossRef] [PubMed]
30. Ziebertz, C.M.; Beckers, D.G.; Van Hooff, M.L.; Kompier, M.A.; Geurts, S.A. The effect on sleep of being on-call: An experimental field study. *J. Sleep Res.* **2017**, *26*, 809–815. [CrossRef]
31. Cotrim, T.; Carvalhais, J.; Neto, C.; Teles, J.; Noriega, P.; Rebelo, F. Determinants of sleepiness at work among railway control workers. *Appl. Ergon.* **2017**, *58*, 293–300. [CrossRef]
32. Mullins, H.M.; Cortina, J.M.; Drake, C.L.; Dalal, R.S. Sleepiness at work: A review and framework of how the physiology of sleepiness impacts the workplace. *J. Appl. Psychol.* **2014**, *99*, 1096. [CrossRef]
33. Honn, K.A.; Satterfield, B.C.; McCauley, P.; Caldwell, J.L.; Van Dongen, H.P.A. Fatiguing effect of multiple take-offs and landings in regional airline operations. *Accid. Anal. Prev.* **2016**, *86*, 199–208. [CrossRef]
34. Borbély, A.A.; Daan, S.; Wirz-Justice, A.; Deboer, T. The two-process model of sleep regulation: A reappraisal. *J. Sleep Res.* **2016**, *25*, 131–143. [CrossRef]
35. Bendak, S.; Rashid, H.S.J. Fatigue in aviation: A systematic review of the literature. *Int. J. Ind. Ergon.* **2020**, *76*, 102928. [CrossRef]

36. Matthews, K.A.; Patel, S.R.; Pantesco, E.J.; Buysse, D.J.; Kamarck, T.W.; Lee, L.; Hall, M.H. Similarities and differences in estimates of sleep duration by polysomnography, actigraphy, diary, and self-reported habitual sleep in a community sample. *Sleep Health* **2018**, *4*, 96–103. [CrossRef] [PubMed]
37. Carskadon, M.A. Guidelines for the multiple sleep latency test (MSLT): A standard measure of sleepiness. *Sleep* **1986**, *9*, 519–524. [CrossRef] [PubMed]
38. Stampi, C.; Stone, P.; Michimori, A. A new quantitative method for assessing sleepiness: The Alpha Attenuation Test. *Work Stress* **1995**, *9*, 368–376. [CrossRef]
39. Rosekind, M.R.; Gregory, K.B.; Mallis, M.M. Alertness management in aviation operations: Enhancing performance and sleep. *Aviat. Space Environ. Med.* **2006**, *77*, 1256–1265. [PubMed]

Graphic design: Communication Division, UIB / Print: Skipnes Kommunikasjon AS

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ISBN: 9788230849293 (print)
9788230855270 (PDF)