HELDA
HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

UNIVERSITY OF HELSINKI

https://helda.helsinki.fi

Self-reported reasons for on-duty sleepiness among commercial airline pilots

Sallinen, M

2021-09-02

Sallinen , M , Onninen , J , Ketola , K , Puttonen , S , Tuori , A , Virkkala , J & Akerstedt , T 2021 , ' Self-reported reasons for on-duty sleepiness among commercial airline pilots ' , Chronobiology International , vol. 38 , no. 9 , pp. 1308-1318 . https://doi.org/10.1080/07420528.2021.1927071

http://hdl.handle.net/10138/344244
https://doi.org/10.1080/07420528.2021.1927071

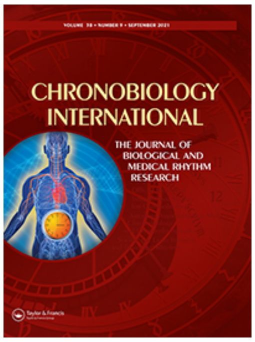
publishedVersion

Downloaded from Helda, University of Helsinki institutional repository.

This is an electronic reprint of the original article.

This reprint may differ from the original in pagination and typographic detail.

Please cite the original version.



Taylor & Francis
Taylor & Francis Group

Chronobiology International
The Journal of Biological and Medical Rhythm Research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/icbi20

Self-reported reasons for on-duty sleepiness among commercial airline pilots

Mikael Sallinen, Jussi Onninen, Kimmo Ketola, Sampsa Puttonen, Antti Tuori, Jussi Virkkala & Torbjörn Åkerstedt

To cite this article: Mikael Sallinen, Jussi Onninen, Kimmo Ketola, Sampsa Puttonen, Antti Tuori, Jussi Virkkala & Torbjörn Åkerstedt (2021) Self-reported reasons for on-duty sleepiness among commercial airline pilots, Chronobiology International, 38:9, 1308-1318, DOI: 10.1080/07420528.2021.1927071

To link to this article: https://doi.org/10.1080/07420528.2021.1927071

Published online: 13 May 2021.

Submit your article to this journal

Article views: 140

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=icbi20

CHRONOBIOLOGY INTERNATIONAL
2021, VOL. 38, NO. 9, 1308–1318
https://doi.org/10.1080/07420528.2021.1927071

Taylor & Francis
Taylor & Francis Group

Check for updates

Self-reported reasons for on-duty sleepiness among commercial airline pilots

Mikael Sallinen[a,b], Jussi Onninen[a,b], Kimmo Ketola[c], Sampsa Puttonen[a], Antti Tuori[c], Jussi Virkkala[a,d], and Torbjörn Åkerstedt[e,f]

[a]Work Ability and Working Careers, Finnish Institute of Occupational Health, Helsinki, Finland; [b]Department of Psychology, University of Jyväskylä, Finland; [c]Finnair, Helsinki, Finland; [d]Department of Clinical Neurophysiology, University of Helsinki and Helsinki University Hospital, University of Helsinki, Helsinki, Finland; [e]Stress Research Institute, Stockholm University, Stockholm, Sweden; [f]Department of Clinical Neuroscience, Karolinska Institute, Stockholm, Sweden

ABSTRACT

Experimental and epidemiological research has shown that human sleepiness is determined especially by the circadian and homeostatic processes. The present field study examined which work-related factors airline pilots perceive as causing on-duty sleepiness during short-haul and long-haul flights. In addition, the association between the perceived reasons for sleepiness and actual sleepiness levels was examined, as well as the association between reporting inadequate sleep causing sleepiness and actual sleep-wake history. The study sample consisted of 29 long-haul (LH) pilots, 28 short-haul (SH) pilots, and 29 mixed fleet pilots (flying both SH and LH flights), each of whom participated in a 2-month field measurement period, yielding a total of 765 SH and 494 LH flight duty periods (FDPs) for analyses (FDP, a period between the start of a duty and the end of the last flight of that duty). The self-reports of sleepiness inducers were collected at the end of each FDP by an electronic select menu. On-duty sleepiness was rated at each flight phase by the Karolinska Sleepiness Scale (KSS). The sleep-wake data was collected by a diary and actigraph. The results showed that "FDP timing" and "inadequate sleep" were the most frequently reported reasons for on-duty sleepiness out of the seven options provided, regardless of FDP type (SH, LH). Reporting these reasons significantly increased the odds of increased on-duty sleepiness (KSS $\geq$ 7), except for reporting "inadequate sleep" during LH FDPs. Reporting "inadequate sleep" was also associated with increased odds of a reduced sleep-wake ratio (total sleep time/amount of wakefulness $\leq$ 0.33). Both "FDP timing" and "inadequate sleep" were most frequently reported during early morning and night FDPs, whereas the other options showed no such phenomenon. The present study suggests that airline pilots' perceptions of work-related factors that make them sleepy at work are in line with the previous experimental and epidemiological studies of sleepiness regulation.

ARTICLE HISTORY
Received 18 November 2020
Revised 19 April 2021
Accepted 3 May 2021

KEYWORDS
Airline pilots; shift work; sleepiness; insufficient sleep; self-perceptions

Introduction

Human sleepiness (i.e., having difficulty staying awake), is strongly determined by the circadian and homeostatic processes (Åkerstedt 2019; Åkerstedt et al. 2014; Goel et al. 2013). In addition, the time needed to fully wake up and the time spent on a task have been generally recognized as important to sleepiness (Sagaspe et al. 2008; Sandberg et al. 2011; Williamson et al. 2011). Many modeling tools that are used to predict on-duty sleepiness in shift work settings are built on these factors and especially the circadian and homeostatic processes (Dawson et al. 2017; Ingre et al. 2014).

Despite numerous studies on regulation of sleepiness, only little is known about shift workers' own perceptions of the factors that make them sleepy at work. Commercial aviation is one of the industries where this topic has been studied most. A survey among long-haul (LH) and short-haul (SH) airline pilots found that these professionals often see night and early morning shifts as causing sleepiness (Bourgeois-Bougrine et al. 2003). These shift schedule characteristics are known to disturb both the circadian and homeostatic processes. In addition, SH pilots perceived a long sequence of consecutive shifts with a high number of sectors as an important factor.

A later study based on fatigue reports by aircrews also proposed that shift schedule characteristics are a primary cause of on-duty sleepiness (Houston et al. 2012). However, that study did not directly ask aircrews about the causes of sleepiness but used a group of experts to identify these causes based on the information collected via a fatigue report form. Interestingly, domestic factors and especially a long commute, were also identified as causes of on-duty sleepiness.

A recent study mapped airline pilots' perceptions of how their working conditions should be developed to

CONTACT Mikael Sallinen mikael.sallinen@ttl.fi Finnish Institute of Occupational Health, P.O. Box 40, Helsinki FI-00251, Finland
This article has been republished with minor changes. These changes do not impact the academic content of the article.
© 2021 Taylor & Francis Group, LLC

reduce on-duty sleepiness (Zaslona et al. 2018). The study found that pilots considered the recommended in-flight sleep procedure efficient as such, but also saw that the way in which the procedure is organized should be further developed to enable pilots to obtain more sleep during rest breaks. In all, the authors concluded that the views and experience of pilots are important to take into consideration when developing sleepiness reduction strategies in aviation.

The aim of the present field study was to examine what work-related factors airline pilots perceive as making them sleepy during SH and LH flights and to what extent these self-perceptions are associated with increased on-duty sleepiness and sleep-wake history. These questions were examined taking into account pilots' state of acclimatization and shift timing (early mornings, mornings, days, evenings, nights), as self-reported reasons for on-duty sleepiness can be expected to vary by the time-of-day factor. Also, shift timing is recognized as a factor in aircrew sleepiness in flight time limitations (COMMISSION REGULATION (EU) No 83/2014). The novelty of the present study lies in the way these questions were examined. Pilots' perceptions of work-related sleepiness inducers and sleepiness levels were measured during each flight duty period (FDP, a period between the start of a duty and the end of the last flight of that duty) and sleep-wake patterns during and outside FDPs throughout the 2-month measurement period.

Material and methods

Ethics statement

The Ethics Board of the Finnish Institute of Occupational Health approved the present study (3/2014), which was conducted in line with the ethical standards of Chronobiology International (Portaluppi et al. 2010). All participants provided written informed consent after being informed about the aim and practicalities of the study. They were not paid for their time or effort.

Participants and flight duty periods

The study sample consisted of 29 LH pilots (flying LH flights only), 28 SH pilots (flying SH flights only), and 29 mixed fleet pilots (flying both SH and LH flights). All participants were male. Originally a questionnaire on well-being at work was sent to all eligible pilots of a middle-sized airline (n = 608). A total of 274 replied to the questionnaire and volunteered for the present field study. Next, a proportional stratified sampling procedure was applied to ensure that the age distribution of each pilot group was in line with the age distribution of all pilots of that particular group within the airline. Of the selected 30 pilots per group, two canceled their participation, one discontinued the measurements, and one was excluded due to long sick leave. The number of participants per pilot group was based on previous pertinent studies and an estimate of a 20% dropout rate (Darwent et al. 2008; Roach et al. 2012; Van Leeuwen et al. 2013).

LH pilots usually had 15 FDPs per 2-month period and several days off between two successive combinations of outbound and inbound FDPs. SH pilots typically had 3–5 consecutive duty days followed by 2–5 consecutive days off. Mixed fleet pilots usually had 10–12 LH FDPs and 4–6 SH FDPs per 2-month period.

Measurements

Before the 2-month field measurements the pilots filled in a questionnaire where they were inquired about their diurnal type ("One hears about "morning" and "evening" types of people. Which one of these types do you consider yourself to be?") (Horne and Östberg 1976), habitual daily sleep time ("How many hours do you sleep, on average, per day including daytime sleeps? Give your estimate based on the past three months"), and daily sleep need ("How many hours of sleep do you need per day to be alert and in good shape at work the next day?"). During the field measurements, the pilots used a hand-held computer (8 inch Windows tablet, Lenovo Miix 2) to report reasons for on-duty sleepiness in the end of each FDP within the 2-month measurement period independent of how many sectors (i.e., single flights) an FDP included. The pilots used the same device to report *their sleepiness* at the following phases of each flight: blocks off (pushing back from the departure gate), top of climb (aircraft reaches cruising altitude), cruise (occurs between top of climb and top of descent), top of descent (pilot initiates descent to final approach altitude), and blocks on (arrival at the destination gate). During the cruise phase, the pilots rated sleepiness every two hours. On-duty sleepiness was measured by the nine-point Karolinska Sleepiness Scale (KSS) with a verbal anchor for each point (Akerstedt et al. 2014).

In addition to the data mentioned above, the pilots used hand-held computers to report their current location (city), work hours (start and end time), naps (timing and duration), and alcohol and coffee consumption once per day at bedtime. Upon awakening, pilots filled in items on sleep (timing, duration, and quality), and the use of sleep-promoting medication. The pilots also wore an actigraph (GENEActiv, © 2015 Activinsights Ltd.) on their non-dominant wrists for collecting objective data on sleep quantity and quality over the whole measurement period. The pilots were instructed to press the event button of the actigraph at lights out and when rising from bed at the end of the sleep period. The raw accelerometer data of GENEActive were analyzed similarly to method by te Lindert et al. (2013). The created epoch data were analyzed by algorithm described by Kushida et al. (2001). First, the maximum peak to peak values of the filtered accelerometer data were calculated for each second. These values were next scaled and summed using 60-second epochs. Finally, a 5-minute window was used to create weighted sums across the data. A medium threshold of 40 was used to separate wake and sleeThe analysis is same as Sleep Analysis software by CamNtech (CamNtech Ltd, Cambridgeshire, UK).

Self-reported reasons for sleepiness

The select menu for reporting reasons for on-duty sleepiness consisted of the following options: a) inadequate sleep due to working hours (called “inadequate sleep” hereafter), b) FDP timing, c) flying for a long period without a break (refers to the time spent on the flight deck and is called “extended time without a break” hereafter), d) conditions in the cockpit (e.g., temperature), e) poor visibility (e.g. weather conditions), f) other factors related to flight arrangements and/or working conditions (called “other flight-related factors” hereafter), and g) other work-related factors. The pilots could select more than one option per FDThe instruction was “If you felt tired or sleepy during your flight, what do you think what was the reason? You may select more than one option. If the reason was mainly not related to your work, leave the options blank.”

All reasons were analyzed separately. In addition, the combination of “FDP timing” and “inadequate sleep” (i.e., a pilot had selected both “FDP timing” and “inadequate sleep” in the select menu) was used, as these two are directly linked to the circadian and homeostatic processes and can be expected to co-occur to a great extent especially during early, late, and night FDPs that affect sleepiness through both processes.

On-duty sleepiness

The main outcome of on-duty sleepiness was the proportion of FDPs including at least one KSS rating ≥ 7 (7 – sleepy, but no effort to keep awake, 8 – sleepy, some effort to keep awake, 9 – very sleepy, great effort to keep awake, fighting sleep). A rating of 7 was selected as cutoff, as increases in physiological and behavioral signs of sleepiness begin to occur at that level of KSS-defined sleepiness (Akerstedt et al. 2014).

Prior sleep

The main outcomes of prior sleep were total sleep time (TST) and the sleep-wake ratio (TST/amount of wakefulness). TST was calculated by summing the actigraphy-defined sleep and the self-estimate of the amount of nap sleep obtained before and during an FDThe rest of the period was considered as wake, that is, all hours that were not flagged as sleeThe sleep-wake ratio (SWR) was calculated for the flight duty days and covered the period between the beginning of the main sleep that preceded an FDP and the end of the FDThe SWR and TST were analyzed as dichotomous variables. For the SWR we used two cutoff criteria for a reduced ratio: ≤ 0.33 (e.g., ≤ 6 h of sleep followed by ≥ 18 h of wakefulness) and < 0.5 (e.g., < 8 h of sleep followed by ≥ 16 h of wakefulness). For reduced TST, ≤ 6 h was used as criterion and for extended wakefulness ≥ 18 h. These cutoffs were based on the current scientific recommendations on the amount of sleep per day for adults (Hirshkowitz et al. 2015). The primary variable for measured inadequate sleep was a significantly reduced SWR (≤ 0.33), as it combined both prior sleep and waking hours.

FDPs

All inbound LH FDPs were divided into those conducted while acclimatized to the home base time zone, those conducted in a state of unknown acclimatization, and those conducted while acclimatized to the layover destination time zone. This division was carried out by a generic formula with the time difference and the time elapsed since reporting at reference time as the factors (COMMISSION REGULATION (EU) No 83/2014). According to this formula, the pilots of the present study were acclimatized to the time zone of their home base (Helsinki) during their LH inbound FDPs if the time elapsed since reporting was < 48 hours, independent of the difference between the reference time (Helsinki) and the local time where the next FDP starts. If the time elapsed since reporting was 48:00–71:59 hours and the difference between the reference time and the local time was 4–7 hours (7 was maximum) the pilots were classified as being in an unknown state of acclimatization. The same held when the time elapsed since reporting was 72:00–95:59 hours and the time difference was 7 hours. Otherwise the pilots were classified as being

Table 1. Descriptive statistics of the pilots who completed the field study. LH = long-haul, Mixed = pilots who flew both long-haul and short-haul flights, SH = short-haul. Means and standard deviations in parentheses.

Individual factors	LH pilots (n = 29)	Mixed pilots (n = 28)	SH pilots (n = 29)	Kruskal-Wallis[1]/Wald chi-square[2] $\chi^2(2)$	P-value
Age, y	45.2 (6.8)	40.6 (6.4)	39.8 (5.8)	10.70[1]	0.005
Flight experience, y	18.9 (7.4)	14.4 (6.4)	14.0 (7.5)	7.37[1]	0.025
Diurnal type, %				1.73[2]	0.442
Morning type	14	24	14		
Evening type	52	59	71		
Intermediate type	34	17	15		
Habitual daily sleep length, h:min	7:17 (0:51)	7:25 (0:48)	7:22 (0:54)	0.43[1]	0.806
Daily sleep need, h:min	8:19 (0:48)	7:59 (0:49)	7:55 (0:49)	4.44[1]	0.109
Body mass index, kg/m^2	26.0 (3.5)	ws25.1 (2.5)	24.3 (2.4)	4.32 [1]	0.115

acclimatized to the local time where the next FDP started.

All the collected FDPs were divided into SHs and LHs and then into the following five categories: early mornings (FDP start time 03:01 h – 05:59 h), mornings (FDP start time 06:00 h – 07:00 h), days (FDP starts at 07:01 at the earliest and ends 18:00 h at the latest), evenings (FDP starts at 07:01 at the earliest and ends between 18:01 h and 02:59 h), and nights (at least 3 hours of the FDP occurs between 23:00 h and 06:00 h) (Härmä et al. 2015). Of these FDP categories, early mornings and nights encroach on the Window of Circadian Low (WOCL, 02:00 h – 05:59 h in the time zone to which a pilot or cabin crew member is acclimatized) by definition and evenings if they end between 02:00 h and 02:59 h (COMMISSION REGULATION (EU) No 83/2014). The flight time of the SH flight was ≤ 6 h and it was operated by a narrow body aircraft, whereas the flight time of LH flight was > 6 h and it was operated by a wide body aircraft.

Statistical analyses

The Shapiro–Wilk test was used to examine the normality of the data. Spearman's rho was used to examine the correlation between individual factors. To study the association between the self-reported reasons of sleepiness and increased on-duty sleepiness (KSS ≥ 7) and between reporting "inadequate sleep" and the SWR, logistic regressions were fit using generalized estimating equations (GEE; Liang and Zeger 1986) that account for within-subject correlation in longitudinal data. SH and LH FDPs were analyzed separately. Binomial distribution of the response variable and logit link function were used. The best correlation structures for the GEE models were determined using the quasi-likelihood under the independence model criterion (QIC; Pan 2001). Alpha was set at .05. All analyses were conducted in R using packages *BCgee* (Lunardon and Scharfstein 2017) and *saws* (Fay and Graubard 2001).

Results

Data description

The descriptive statistics of the participants are given in Table 1. The pilot groups were significantly different in terms of age and flight experience but not in terms of the other individual characteristics. Age and flight experience were strongly correlated ($r_s = 0.87$, $p < .001$). Furthermore, diurnal type and habitual sleep need showed a significant correlation ($r_s = 0.28$, $p = .008$), with evening types reporting longer habitual sleep need. The other correlations were not significant (all $p > .05$).

The field data of the LH, SH, mixed fleet groups consisted of 383, 701, and 532 FDPs, respectively. Of these 1616 FDPs, 1259 included data on self-reported reasons for sleepiness, self-rated sleepiness, and data needed to determine a state of acclimatization. The number and proportion of SH FDPs were 765 and 61% and those of long-haul FDPs 494 and 39%. Of the analyzed 765 SH FDPs, 6 (0.8%) contained 5 sectors, 48 (6.3%) 4 sectors, 114 (14.9%) 3 sectors, 420 (54.9%) 2 sectors, and 177 SH FDPs (23.1%) contained 1 sector. The mean number of KSS ratings given during the cruise phase was 0.74 (SD 0.62) for SH FDPs and 2.65 (SD 0.91) for LH FDPs. Of the analyzed outbound LH FDPs 86.5% were from Helsinki to the Far East or India (time difference +3.5 – +7 h) and the remaining 13.5% to the Americas (time difference −7 h). Of the analyzed inbound LH FDPs, 89.9% departed from the Far East or India and the remaining 10.1% from the Americas. One hundred six LH inbound FDPs were conducted in an unknown state of acclimatization. In these cases the time elapsed since reporting at reference time was 62:10 hours (SD 8:15 hours) and the difference between local and home base time (Helsinki) 5–7 hours. Three LH inbound FDPs were conducted while acclimatized to the layover destination time zone. These were removed from the data before the actual analyses due to a small number of observations.

Self-reported reasons for sleepiness

The two most frequent reasons for sleepiness were "FDP timing" (19% of SH FDPs and 71%-79% of LH FDPs) and "inadequate sleep" (32% of SH FDPS and 47%-79% of LH FDPs) (Table 2). In addition, the combination thereof was rather common among LH FDPs (42%-68%), but not among SH FDPs (9%). Among the rest of the reasons, only "extended time on task" stood out but only during LH FDPs (17%-30%). Otherwise the reasons other than the three mentioned above were reported rarely (1% – 12%).

When only the FDPs that included increased sleepiness (KSS ≥ 7 at least once) were selected, the proportion of FDPs with "FDP timing", "inadequate sleep", and both these reasons increased especially among SH FDPs. The same held for SH FDPs with "other work-related factors". A logistic regression analysis was conducted to test the association between the most frequently reported sleepiness inducers with increased on-duty sleepiness. Reporting "FDP timing" was associated with increased odds of on-duty sleepiness (dichotomous KSS variable with ≥ 7 as cutoff) during both FDP types (SH FDP: crude OR = 4.96, 95% CI 2.86:8.61, $p < .001$; LH FDPs: crude OR = 3.44, 95% CI 2.18:5.44, $p < .001$). The same held for "inadequate sleep" but only during SH FDPs (SH FDP: crude OR = 2.63, 95% CI 1.61:4.30, $p < .001$; LH FDP: crude OR = 1.44, 95% CI 0.91:2.27, $p = .13$).

Table 3 shows the proportion of FDPs with reduced TST (≤ 6 h), extended wakefulness (≥ 18 h), and a reduced SWR (< 0.5 or ≤ 0.33) as a function of whether "inadequate sleep" was reported.

In all FDP categories, the proportion of FDPs with SWR ≤ 0.33 was greater among FDPs with that self-report than without. A similar pattern was found for the other sleep-wake outcomes in most of the FDP categories, except for extended wakefulness (≥ 18 h). The proportion of FDPs with extended wakefulness tended to be either at a similar or even a higher level when "inadequate sleep" was not reported.

Another main finding was that at most only 28% of the FDPs with "inadequate sleep" had an SWR ≤ 0.33,

Table 2. Proportion (%) of FDPs with different self-reported reasons for sleepiness broken down by FDP type. The results are shown separately for FDPs that included sleepiness (KSS ≥ 7). Inbound LH FDPs have been divided into those conducted while acclimatized to the home base time zone (hb) and those conducted in an unknown state of acclimatization (un).

Self-reported reason	All SH FDPs (n = 765)	*All SH FDPs with KSS ≥ 7 (n = 67)*	All LH FDPs (n = 494)	*All LH FDPs with KSS ≥ 7 (n = 280)*	LH outbound FDPs (n = 287)	*LH outbound FDPs with KSS ≥ 7 (n = 152)*	Inbound LH FDPs (hb) (n = 101)	*LH inbound FDPs with KSS ≥ 7 (hb) (n = 51)*	Inbound LH FDPs (un) (n = 106)	*LH inbound FDPs with KSS ≥ 7 (un) (n = 77)*
FDP timing	19	*54*	77	*87*	77	*90*	71	*73*	79	*91*
Inadequate sleep	32	*61*	54	*61*	39	*47*	79	*84*	71	*74*
FDP timing + inadequate sleep	9	*33*	44	*53*	33	*42*	60	*65*	57	*68*
Extended time on task	7	*12*	23	*26*	22	*22*	17	*22*	30	*38*
Cockpit conditions	3	*6*	3	*4*	4	*5*	3	*2*	3	*4*
Visibility	2	*1*	2	*3*	2	*1*	3	*6*	3	*4*
Other flight-related factors	10	*13*	7	*9*	6	*8*	5	*4*	11	*16*
Other work-related factors	12	*22*	5	*7*	6	*9*	1	*0*	9	*9*

Table 3. Proportion (%) of short-haul (SH) and long-haul (LH) FDPs with total sleep time (TST) ≤ 6 h, wakefulness ≥ 18 h, and the sleep-wake ratio (SWR) <0.5 and ≤ 0.33 broken down by whether inadequate sleep was self-reported as a reason for on-duty sleepiness. Inbound LH FDPs have been divided into those conducted while acclimatized to the home base time zone (hb) and those conducted in an unknown state of acclimatization (un).

Sleep-wake measure	SH FDPs		All LH FDPs		LH outbound FDPs		LH inbound FDPs (hb)		LH inbound FDPs (un)	
	Inadequate sleep reported (n = 209)	Inadequate sleep not reported (n = 483)	Inadequate sleep reported (n = 259)	Inadequate sleep not reported (n = 207)	Inadequate sleep reported (n = 96)	Inadequate sleep not reported (n = 151)	Inadequate sleep reported (n = 113)	Inadequate sleep not reported (n = 40)	Inadequate sleep reported (n = 50)	Inadequate sleep not reported (n = 16)
TST ≤ 6 h	37	18	31	10	3		48	25	46	25
Wakefulness ≥ 18 h	3	3	41	50	69	54	19	32	34	50
SWR <0.5	29	27	80	73	85	74	73	65	86	88
SWR ≤ 0.33	4	2	21	10	21	12	19	3	28	13

whereas even 86% of these FDPs had an SWR < 0.5. Thirdly, the proportion of FDPs with a reduced SWR was greater among LH FDPs than SH FDPs, regardless of whether "inadequate sleep" was reported. For extended wakefulness (≤ 18 h), a similar phenomenon was observed but not for reduced TST (≤ 6 h).

An additional analysis showed that 31% of the SH FDPs and 58% of the LH FDPs with an SWR < 0.5 included a self-report of "inadequate sleep". Under the criterion of ≤0.33, the corresponding values were 53% for SH FDPs and 72% for LH FDPs. For SH and LH FDPs with TST ≤ 6 h, these values were 47% and 80%, respectively. Of the SH and LH FDPs with wakefulness ≥ 18 h, 32% and 50% contained "inadequate sleep", respectively.

A logistic regression analysis was used to test the association with reporting "inadequate sleep" and an SWR ≤ 0.33 (primary variable for measured inadequate sleep). Reporting "inadequate sleep" was associated with significantly increased odds of a reduced SWR (≤ 0.33) during LH FDPs, but not during SH FDPs (SH FDP: crude OR = 2.48, 95% CI 0.97:6.34, p = .096; LH FDPs: crude OR = 2.58, 95% CI 1.38:4.85, p = .03).

Self-reported reasons for sleepiness based on FDP timing

Figure 1 shows SH and LH FDPs and prior sleeps in the early morning, morning, day, evening and the night FDP categories. A general observation was that LH FDPs were longer in duration and more frequently encroached on the WOCL than SH FDPs. The mean duration of SH FDPs was 8:00 hours (SD 1:46 hours) and that of LH FDPs 11:23 hours (SD 1:27 hours). The same phenomenon was found for early mornings (SHs 9.26 (SD 2.10) vs LHs 11.63 (SD 0.97)), evenings (SHs 7.81 (SD 1.67) vs LHs 10.84 (SD 1.13), and nights (SHs 9.8 (SD 1.96) vs LHs 11.40 (SD 1.65)). Of all LH FDPs, 91% encroached on the WOCL (as determined in home base time), whereas only 9% of all SH FDPs did the same.

Table 4 shows the proportion of SH and LH FDPs with different reasons for sleepiness and KSS ≥ 7 broken down by shift timing. A main finding was that FDPs with "FDP timing", "inadequate sleep" showed high proportions especially during early SH early morning FDPs (67% and 76%, respectively), LH night outbound FDPs (86% and 71%, respectively), LH inbound early morning FDPs when acclimatized to the time zone of the home base (71% and 80%, respectively), LH inbound early morning FDPs flown in an unknown state of acclimatization (71% and 81%), and during LH inbound night FDPs flown in an unknown state of acclimatization (87% and 61%,

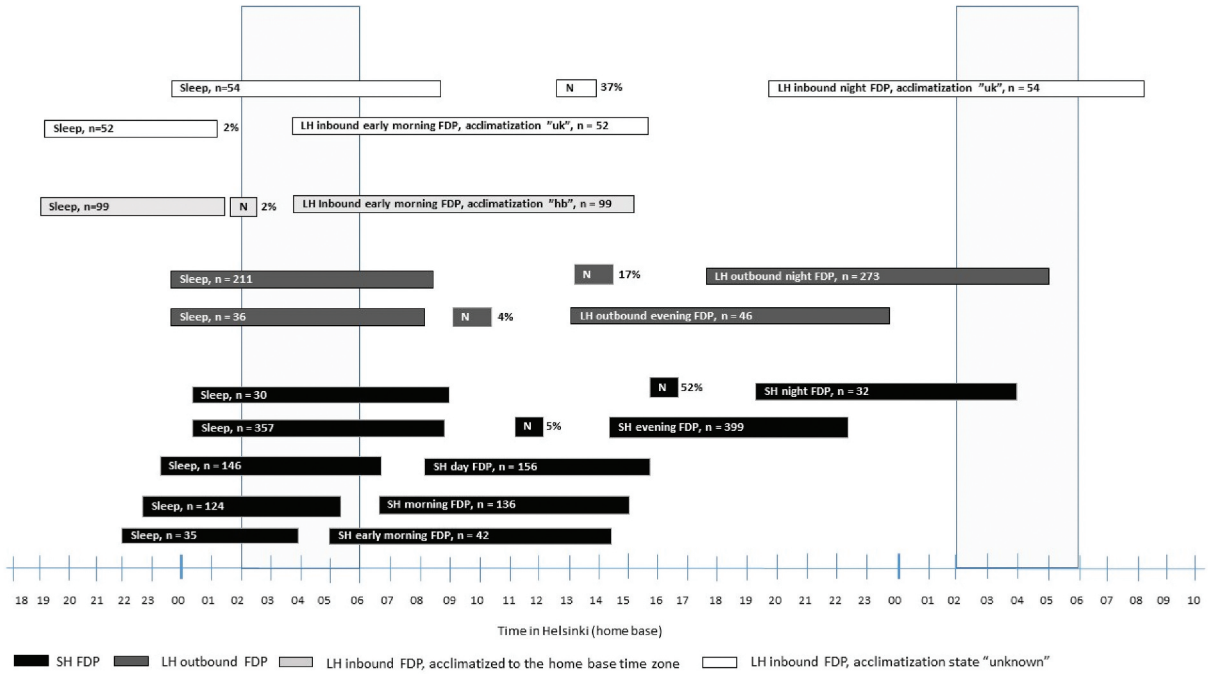


Figure 1. SH and LH FDPs classified into early mornings, mornings, days, evenings, and nights. Inbound LH FDPs have been divided into those conducted while acclimatized to the home based time zone (hb) and those conducted in an unknown state of acclimatization (un). The right-hand horizontal bars denote mean periods between FDP start and end times. The left-hand horizontal bars denote mean sleep periods prior to FDPs. Percent values next to pre-duty naps (N) show the proportions of cases including such a nap. The vertical gray bars denote the Window of Circadian Low (WOCL, 02:00 h-05:59 h). The results are shown only when the number of FDPs was ≥ 10.

respectively). Also the combination of these two reasons showed relatively high proportions (39% – 61%) during the same FDPs. The highest single proportion was, however, observed for "FDP timing" during SH night FDPs (94%) but in this case the proportion of FDPs with "inadequate sleep" was rather low (25%).

The proportions of the rest of the reasons remained below 25%, except for "other work-related factors" during SH night FDPs (28%) and "extended time on task" during LH evening outbound FDPs (40%) and LH early morning and night inbound FDPs conducted in an unknown state of acclimatization (29% and 32%, respectively).

FDPs with KSS rating ≥ 7 showed the highest proportions during LH FDPs (52% – 78%), except for LH outbound evening FDPs (19%). Of the SH FDPs, early

Table 4. Proportion (%) of FDPs with different self-reported reasons for sleepiness and KSS ≥ 7 classified into early mornings, mornings, days, evenings, and nights. LH inbound FDPs have been divided into those conducted while acclimatized to the home base time zone (hb) and those conducted in an unknown state of acclimatization (un).

	SH FDPs					LH outbound FDPs		LH inbound FDPs (hb)	LH inbound FDPs (un)	
Outcome	Early morning (n = 42)	Morning (n = 136)	Day (n = 156)	Evening (n = 399)	Night (n = 32)	Evening (n = 46)	Night (n = 273)	Early morning (n = 99)	Early morning (n = 52)	Night (n = 54)
FDP timing	67	24	8	11	94	28	86	71	71	87
Inadequate sleep	76	50	42	17	25	16	43	80	81	61
FDP timing + inadequate sleep	52	12	6	3	25	2	39	61	60	54
Extended time on task	17	4	3	8	13	40	19	17	29	32
Cockpit conditions	7	3	1	3	0	0	5	3	4	2
Visibility	2	1	1	3	6	2	2	3	0	6
Other flight-related factors	7	7	12	11	15	9	6	4	12	11
Other work-related factors	10	11	11	11	28	7	6	1	6	11
KSS ≥ 7	29	12	10	4	22	19	59	52	67	78

Table 5. Proportion (%) of FDPs with total sleep time (TST) ≤ 6 h, wakefulness ≥ 18 h, and the sleep-wake ratio (SWR) <0.5 and ≤ 0.33 classified into early mornings, mornings, days, evenings, and nights. LH inbound FDPs have been divided into those conducted while acclimatized to the home base time zone (hb) and those conducted in an unknown state of acclimatization (un).

	SH FDPs					LH outbound FDPs		LH inbound FDPs (hb)	LH inbound FDPs (un)	
Outcome	Early morning (n = 35)	Morning (n = 124)	Day (n = 146)	Evening (n = 357)	Night (n = 30)	Evening (n = 36)	Night (n = 211)	Early morning (n = 99)	Early morning (n = 52)	Night (n = 54)
TST ≤ 6 h	69	54	23	11	7	6	3	55	56	9
Wakefulness ≥ 18 h	0	0	0	1	74	2	70	0	2	93
SWR <0.5	46	15	6	35	83	53	83	69	79	83
SWR ≤ 0.33	6	2	0	2	17	3	18	12	19	20

mornings and nights showed the highest proportions (29% and 22%, respectively).

Of the sleep-wake outcomes, the proportion of FDPs with TST ≤ h 6 was highest during early morning FDPs, whereas that of FDPs with wakefulness ≥ 18 h peaked during night FDPs (Table 5). The proportion of FDPs with a reduced SWR (< 0.5 or ≤ 0.33) was highest during all night FDPs and during LH early morning inbound FDPs.

Discussion

Main results

A main finding of the present study was that airline pilots perceived FDP timing and inadequate sleep due to working hours as the main reasons for on-duty sleepiness during both SH and LH FDPs. These reasons were reported most frequently during early mornings and night FDPs that encroached on the WOCL. The other work-related reasons – extended time without a break, conditions in cockpit, poor visibility, other flight-related factors, and other work-related factors – were reported only rarely. Reporting “FDP timing” and “inadequate sleep” were associated with increased odds of on-duty sleepiness. In addition, both reporting these reasons and on-duty sleepiness peaked during early mornings and nights. In addition, reporting “inadequate sleep” was associated with increased odds of a significantly reduced SWR in connection with LH FDPs.

Comparison of the present results with earlier ones

In all, the results show that airline pilots’ perceptions of the work-related factors that make them sleepy on duty are well in line with experimental and observational studies on the regulation of sleepiness in shift work (Akerstedt et al. 2014; Goel et al. 2013). Both the former and the latter show that factors that exert their effects directly through the circadian and homeostatic processes play the primary role. According to the present study, a possible exception to this rule may be the time-on-task factor especially when a job is characterized by long and monotonous task periods as is the case for LH FDPs. On the other hand, the possibility to have a scheduled in-flight rest break during LH FDPs probably reduces the likelihood that the pilot would perceive the time-on-task factor or “inadequate sleep” as sleepiness inducers. In our data, 73% of the LH FDPs included this rest opportunity, whereas during SH FDPs such an opportunity was not available.

The results of the present field study are also congruent with the survey-based study of Bourgeois-Bourgrine et al. (2003). In that study, factors directly related to the homeostatic and circadian processes (e.g., having night duties and early starts) were perceived by LH and SH pilots as primary reasons for on-duty fatigue. On the other hand, Bourgeois-Bourgrine et al. also found that flying 4–5 legs within an SH FDP was frequently reported as a source of fatigue. The present study found no such evidence. The inconsistency may be explained by the fact that only 7.1% of SH FDPs of the present study contained more than three sectors, which made it difficult to determine the role of this shift characteristic. Second, the level of sectors as a sleepiness inducer was not directly asked in the present study but that reason probably fell into a rather broad category named “other flight arrangements”. Thus, it is difficult to evaluate the extent to which airline pilots consider multiple sectors as making them sleepy based on the present study. In addition, it is possible that especially the options of “other flight-related factors” and “other work-related factors” were formulated so broadly that they might have easily been left blank by the pilots. In future studies, it would be important to provide participants with a higher number of well-defined options than in the present study as well as an option to report in their own words. This methodological improvement might reveal sleepiness inducers that were not found in the present study.

Role of circadian influence

The found distribution of FDPs with "FDP timing" and "inadequate sleep" across early mornings, mornings, days, evenings, and nights mirrors well the temporal distribution of the circadian influences on sleepiness and sleep sufficiency (Czeisler and Buxton 2017; Gabehart and Van Dongen 2017). In addition to these two self-reports, increased on-duty sleepiness and a reduced sleep-wake ratio showed a similar distribution. Thus, the circadian process is probably the main factor behind the found associations of reporting FDP timing" and "inadequate sleep" with increased on-duty sleepiness and a reduced SWR.

The circadian influence probably also mainly explains the observed differences in reporting "FDP timing", "inadequate sleep", and the combination thereof between SH and LH FDPs. Ninety-one percent of LH FDPs, but only 9% of SH FDPs, encroached on the WOCL. Interestingly, the difference in reporting these causes for sleepiness largely disappeared when SH and LH FDPs were analyzed separately in the early morning, evening, and night categories, even though the difference in FDP duration remained quite the same between the FDP types. The highest proportions of FDPs with "FDP timing", "inadequate sleep", and the combination thereof were seen during FDPs that encroached on the WOCL (early mornings and nights) in both FDP types. In all, these results suggest that an encroachment on the WOCL is more important than FDP type in terms of what factors pilots perceive as making them sleepy. For the rest of the reasons for on-duty sleepiness, no clear circadian influence was observed in any of the FDP categories.

Interestingly, no evidence of the role of the state of acclimatization in self-perceived reasons for on-duty sleepiness was found. For example, the results of LH outbound night FDPs and LH inbound FDPs conducted in an unknown state of acclimatization were quite similar. The same held for the results of LH inbound early morning flights flown while acclimatized to the home base time zone and conducted in an unknown state of acclimatization. Our result does not, however, mean that the state of acclimatization would not be a significant factor. First, the determination of a state of acclimatization was based only on a generic formula with the time difference and the time elapsed since reporting as the factors (COMMISSION REGULATION (EU) No 83/2014, 2014). Secondly, our data did not allow us to compare FDPs conducted while acclimatized to the home base time zone vs. the layover destination time zone. To further address this issue, an experimental approach would probably be needed to systematically manipulate the state of acclimatization while keeping other influential factors constant.

Association between reported reasons for sleepiness and the level of sleepiness

An interesting question is to what extent self-perceptions of sleepiness inducers could be used to assess the severity of on-duty sleepiness. Generally, it may be easier for the individual in a safety-critical occupation to report reasons for his/her sleepiness than an exact level of sleepiness itself.

As mentioned above, the present study suggests that the most frequently reported sleepiness inducers, FDP timing and inadequate sleep, are associated with increased on-duty sleepiness. First, the proportion of FDPs with these reasons was higher among FDPs that contained increased sleepiness than among all FDPs, regardless of FDP type. Second, reporting "FDP timing" or "inadequate sleep" significantly increased the odds of on-duty sleepiness, except for reporting "inadequate sleep" during LH FDPs.

In all, these results support the notion that self-reports of "FDP timing" and "inadequate sleep" causing sleepiness might be relevant indicators of significant sleepiness levels. However, it is also important to consider that there seems to be a relatively significant proportion of FDPs with increased sleepiness during which neither "FDP timing" nor "inadequate sleep" are reported. To use self-reports of sleepiness inducers as indicators of the severity of on-duty sleepiness, further research is needed to especially clarify if there are certain FDP characteristics or combinations thereof that explain more the congruence between self-reports of sleepiness inducers and significantly increased on-duty sleepiness.

Association between reporting "inadequate sleep" and sleep-wake history

The association of reporting "inadequate sleep" with non-optimal sleep-wake history was examined as an additional question in the present study. The results suggest that the former is associated with the latter during LH FDPs but to a lesser extent during SH FDPs when using an SWR ≤ 0.33 as the criterion. On the other hand, FDPs with "inadequate sleep" seem to cover mostly FDPs with moderately ($0.33 < \text{SWR} < 0.5$) rather than severely (≤ 0.33) reduced SWRs, regardless of FDP type. For example, 80% of the LH FDPs with "inadequate sleep" showed an SWR < 0.5 whereas only 21% of the same FDPs showed an SWR ≤ 0.33.

Also, a significant proportion of SH FDPs with an SWR ≤ 0.33, TST ≤ 6 h, and wakefulness ≥ 18 h did not include a self-report of "inadequate sleep". This finding suggests that non-optimal sleep-wake history is often not perceived by airline pilots as causing sleepiness during these FDPs. For LH FDPs, these proportions were clearly lower suggesting that, as opposed to SH FDPs, objectively detected deteriorations in sleep-wake history is rather frequently reflected in self-perceptions of sleepiness inducers during these flights. This difference may be explained by a low proportion of SH FDPs encroaching on the WOCL in the present data.

Limitations and strengths

The present study focused on only one, male-dominated shift-working population, which raises the question about the generalizability of the results. It can be assumed that the work-related factors that shift workers perceive as making them sleepy vary at least to some extent by job characteristics. This assumption is supported by the differences found between SH and LH FDPs in the present study. In addition, there are also physically demanding jobs and jobs with a lot of social interaction. These activities are known to reduce subjective sleepiness (Akerstedt et al. 2014) and thus, it is possible that these activities also affect self-perceptions of sleepiness inducers. Also, airline pilots can be considered a special shift-working population, as they are often better trained than many other groups of shift workers on the basics of sleep and sleepiness and their job has many unique aspects, such as crossing time zones.

Another limitation of the present study is the inclusion of only seven pre-defined work-related factors in the list of sleepiness inducers. There may be other relevant work-related, and also domestic factors, that play a role in aircrew sleepiness (Houston et al. 2012).

In addition, it is worth noticing that the results of the association between the self-reported reasons for sleepiness and the level of on-duty sleepiness may be affected by the way on-duty sleepiness was defined. As the pilots rated sleepiness during each flight within each FDP and every second hour in the cruise phase, the number of ratings and thus also the chance of rating KSS ≥ 7 varied by the number and duration of flights.

The main strengths of the present study are the use of rich field data and being able to combine self-perceptions of reasons for sleepiness with on-duty sleepiness and actigraphy-based sleep-wake patterns. In addition, the present study made it possible to examine both SH and LH FDPs and take into account FDP start time as a factor.

Conclusions

In conclusion, the present study suggests that airline pilots perceive FDP timing and inadequate sleep due to their working hours as the main work-related reasons for on-duty sleepiness. These two reasons are also closely associated with the occurrence of significant sleepiness levels. Other potential work-related reasons, such as cockpit and weather conditions, and flight arrangements, do not seem to be among the key factors in the present context. An exception to this rule may be extended time on task during LH FDPs and the number of sectors during SH FDPs. In all, the results of the present study do not indicate any strong need to enter other types of work-related factors into the equation than those directly exerting their effects through the circadian and homeostatic processes when assessing pilot on-duty sleepiness. In addition, the present study strongly supports the notion of FDP timing, alongside FDP duration, as a factor in regulations of duty hour and sleepiness reduction strategies.

Acknowledgements

This study was supported by Finnair, the Finnish Institute of Occupational Health, and NordForsk, Nordic Programme on Health and Welfare under Grant (no. 74809).

Funding

This study was supported by Finnair, the Finnish Institute of Occupational Health, and NordForsk, Nordic Programme on Health and Welfare under Grant [no. 74809].

ORCID

Jussi Onninen http://orcid.org/0000-0002-0082-0792
Torbjörn Åkerstedt http://orcid.org/0000-0001-8049-8504

Declaration of interest

The authors report no conflict of interest.

References

Åkerstedt T. 2019. Shift work - sleepiness and sleep in transport. Sleep Med Clin. 14:413–421. doi:10.1016/j.jsmc.2019.07.003.

Akerstedt T, Anund A, Axelsson J, Kecklund G. 2014. Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. J Sleep Res. 23:240–252. doi:10.1111/jsr.12158.

Bourgeois-Bougrine S, Carbon P, Gounelle C, Mollard R, Coblentz A. 2003. Perceived fatigue for short- and long-haul flights: a survey of 739 airline pilots. Aviat Space Environ Med. 74:1072–1077.

COMMISSION REGULATION (EU) No 83/2014. 2014. Official Journal of the European Union. [accessed 2020 Oct 26]. https://eur-lex.europa.eu/LexUr7iServ/LexUriServ.do?uri=OJ:L:2014:028:0017:0029:EN:PDF .

Czeisler C, Buxton OM. 2017. Human circadian timing system and sleep-wake regulation. In: Kryger M, Roth T, editors. Principles and practice of sleep medicine. 6th ed. Philadelphia, PS: Elsevier; p. 362–376.

Darwent D, Lamond N, Dawson D. 2008. The sleep and performance of train drivers during an extended freight-haul operation. Appl Ergon. 39:614–622. doi:10.1016/j.apergo.2008.02.012.

Dawson D, Darwent D, Roach GD. 2017. How should a bio-mathematical model be used within a fatigue risk management system to determine whether or not a working time arrangement is safe? Accid Anal Prev. 99(469–473):469–473. doi:10.1016/j.aap.2015.11.032.

Fay MP, Graubard BI. 2001. Small-sample adjustments for Wald-type tests using sandwich estimators. Biometrics. 57 (4):1198–1206. doi:10.1111/j.0006-341X.2001.01198.

Gabehart RJ, Van Dongen HPA. 2017. Circadian rhythms in sleepiness, alertness, and performance. human circadian timing system and sleep-wake regulation. In: Kryger M, Roth T, editors. Principles and practice of sleep medicine. 6th ed. Philadelphia, PS: Elsevier; p. 388–395.

Goel N, Basner M, Rao H, Dinges DF. 2013. Circadian rhythms, sleep deprivation, and human performance. Prog Mol Biol Transl Sci. 119:155–190. doi:10.1016/B978-0-12-396971-2.00007-5.

Härmä M, Ropponen A, Hakola T, Koskinen A, Vanttola P, Puttonen S, Sallinen M, Salo P, Oksanen T, Pentti J, Vahtera J, Kivimäki M. 2015. Developing register-based measures for assessment of working time patterns for epidemiologic studies. Scand J Work Environ Health. 41:268–79. doi:10.5271/sjweh.3492

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. 1:40–43. doi:10.1016/j.sleh.2014.12.010.

Horne JA, Östberg O. 1976. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. Int J Chronobiol. 4:97–110.

Houston S, Dawson K, Butler S. 2012. Fatigue reporting among aircrew: incidence rate and primary causes. Aviat Space Environ Med. 83:800–804. doi:10.3357/asem.3238.2012.

Ingre M, Van Leeuwen W, Klemets T, Ullvetter C, Hough S, Kecklund G, Karlsson D, Åkerstedt T. 2014. Validating and extending the three process model of alertness in airline operations. PLoS One. 9:e108679. doi:10.1371/journal.pone.0108679.

Kushida CA, Chang A, Gadkary C, Guilleminault C, Carrillo O, Dement WC. 2001. Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters in sleep-disordered patients. Sleep Med. 2:389–396. doi:10.1016/s1389-9457(00)00098-8.

Liang KY, Zeger SL. 1986. Longitudinal data analysis using generalized linear models. Biometrika 73:13–22. doi:10.1093/biomet/73.1.13

Lunardon N, Scharfstein D. 2017. Comment on 'Small sample GEE estimation of regression parameters for longitudinal data'. Stat Med. 36(22):3596–3600. doi:10.1002/sim.7366

Pan W. 2001. Akaike's information criterion in generalized estimating equations. Biometrics 57:120–125. doi:10.1111/j.0006-341X.2001.00120.x

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

Roach GD, Petrilli RM, Dawson D, Lamond N. 2012. Impact of layover length on sleep, subjective fatigue levels, and sustained attention of long-haul airline pilots. Chronobiol Int. 29:580–586. doi:10.3109/07420528.2012.675222.

Sagaspe P, Taillard J, Akerstedt T, Bayon V, Espié S, Chaumet G, Bioulac B, Philip P. 2008. Extended driving impairs nocturnal driving performances. PLoS One. 3: e3493. doi:10.1371/journal.pone.0003493.

Sandberg D, Anund A, Fors C, Kecklund G, Karlsson JG, Wahde M, Åkerstedt T. 2011. The characteristics of sleepiness during real driving at night–a study of driving performance, physiology and subjective experience. Sleep. 34:1317–1325. doi:10.5665/SLEEP.1270.

te Lindert BHW, van Someren EJW. 2013. Sleep estimates using microelectromechanical systems (MEMS). Sleep 36:781–789. doi:10.5665/sleep.2648

van Leeuwen WM, Kircher A, Dahlgren A, Lützhöft M, Barnett M, Kecklund G, Åkerstedt T. 2013. Sleep, sleepiness, and neurobehavioral performance while on watch in a simulated 4 hours on/8 hours off maritime watch system. Chronobiol Int. 30:1108–1115. doi:10.3109/07420528.2013.800874.

Williamson A, Lombardi DA, Folkard S, Stutts J, Courtney TK, Connor JL. 2011. The link between fatigue and safety. Accid Anal Prev. 43:498–515. doi:10.1016/j.aap.2009.11.011.

Zaslona JL, O'Keeffe KM, Signal TL, Gander PH. 2018. Shared responsibility for managing fatigue: hearing the pilots. PLoS One. 13:e0195530. doi:10.1371/journal.pone.0195530.