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Sleep, alertness and alertness management among commercial airline pilots on short-haul and long-haul flights

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Airline pilots' sleep and on-duty alertness are important focus areas in commercial aviation. Until now, studies pertaining to this topic have mainly focused on specific characteristics of flights and thus a comprehensive picture of the matter is not well established. In addition, research knowledge of what airline pilots actually do to maintain their alertness while being on duty is scarce.

To address these gaps in research knowledge, we conducted a field study on a representative sample of the airline pilots of a medium-sized airline. The sample consisted of 90 pilots, of whom 30 flew long-haul (LH) routes, 30 short-haul (SH) routes, and 30 flew both. A total of 86 pilots completed the measurements that lasted for almost two months per pilot. The measurements resulted in a total of 965 flight duty periods (FDPs) including SH flights and 627 FDPs including LH flights. During the measurement periods, sleep was measured by a diary and actigraphs, on-duty alertness by the Karolinska Sleepiness Scale (KSS) in all flight phases, and on-duty alertness management strategies by the diary.

Results showed that SH and LH FDPs covering the whole domicile night (00:00–06:00 at home base) were most consistently associated with reduced sleep-wake ratio and subjective alertness. Approximately every 3rd FDP falling into this category involved a reduced sleep-wake ratio (1:3 or lower) and every 2nd a reduced level of subjective alertness (KSS rating 8–9 in at least one flight phase). The corresponding frequencies for the SH and LH FDPs that partly covered the domicile night were every 10th and every 5th FDP and for the pure non-night FDPs every 30th and every 36th FDP, respectively. The results also showed that the pilots tended to increase the use of effective on-duty alertness management strategies (consuming alertness-promoting products and taking strategic naps) in connection with the FDPs that overlapped the domicile night. Finally, the results showed that the frequency of flights involving reduced subjective alertness depended on how alertness was assessed. If it was assessed solely in the flight phase just before starting the landing procedures (top of descent) the phenomenon was less frequent than if the preceding cruise phase was also taken into account.

Our results suggest that FDPs covering the whole domicile night should be prioritised over the other FDPs in fatigue management, regardless of whether an FDP is a short-haul or a long-haul. In addition, the identification of fatigue in flight operations requires one to assess pilots' alertness across all flight phases, not only at ToD. Due to limitations in our data, these conclusions can, however, be generalise to only LH FDPs during which pilots can be expected to be well acclimatised to the local time at their home base and SH night FDPs that include at least 3 h of flying in the cruise phase.

1. Introduction

Sleepiness and shortage of sleep are known to be safety hazards in many 24/7 industries (Sallinen and Hublin, 2015; Sallinen and Kecklund, 2010). In this study, we focus on one of these industries,

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namely commercial aviation, and examine airline pilots whose job is characterised by irregular working hours and high demands for alertness.

Across the 24/7 industries, the timing and duration of work shifts and the rest time between consecutive work shifts are amongst the most important determinants of employees' sleep and on-duty alertness (Sallinen and Hublin, 2015; Sallinen and Kecklund, 2010) and commercial aviation makes no exception (Gander et al., 2013, 2015; Powell et al., 2007, 2008; Roach et al., 2012a, b; Vejvoda et al., 2014). In addition to these common determinants, airline pilots' sleep and alertness are affected by factors specific for their job, such as the phase of flight, the duration of layover, and the number of flight segments within a flight duty period (Gander et al., 2014a,b; Honn et al., 2016; Powell et al., 2007; Roach et al., 2012a).

Until now, studies on airline pilots' sleep and alertness have either concentrated on limited types of flights, such as long-haul on a certain route, or some specific elements of flights (Gander et al., 2013; Honn et al., 2016; Roach et al., 2012a,b). For this reason, it is difficult to create a comprehensive picture of airline pilots' sleep and alertness on different duty rosters and different types of routes. In addition, only little is known about airline pilots' on-duty alertness management strategies on different types of routes, with the exception of strategic napping (Hartzler, 2014). The extent to which different strategies are used, however, affects airline pilot's alertness.

To fill these gaps in knowledge we conducted a field study on a representative sample of the long-haul, short-haul, and mixed fleet (flying both long-haul and short-haul flights) pilots of a medium-sized airline. We measured pilots' sleep-wake patterns and on-duty alertness levels and management strategies for a period of almost two months while the pilots were working on their typical monthly duty rosters.

2. Material and methods

2.1. Ethics statement

The study was approved by the Ethics Committee of the Finnish Institute of Occupational Health. All participants provided written informed consent prior to starting the field measurements. Participants were not paid for their time or effort.

2.2. Participants and flight duty periods

Participants were selected from a group of 274 pilots who replied to a questionnaire on well-being at work and volunteered for the field study. The questionnaire was originally sent to all 608 eligible pilots of the airline (response rate 79%). Thirty long-haul (LH) pilots (flying LH flights only), 30 short-haul (SH) pilots (flying SH flights only), and 30 mixed fleet pilots (flying both the SH and LH flights) were finally selected for the field study out of the 274 volunteers. The selection process followed a proportional stratified sampling procedure to make the age distribution in each group equal to the age distribution of all pilots in that particular group within the participating airline. A total of 29 LH, 28 SH, and 29 mixed fleet pilots completed the field measurements resulting in a total of 383, 701, and 532 flight duty periods (FDPs), respectively. Of these FDPs, all those that included SH flights (scheduled flight time $\leq$ 6 h, operated by narrow body aircrafts) and 96% of those that included LH flights (scheduled flight time > 6 h, operated by wide body aircrafts) were utilised in the statistical analyses. The excluded LH FDPs were operated to destinations that were rare and deviated geographically from the other destinations. The descriptive statistics of the pilots are given in Table 1. The table also shows the corresponding figures of all eligible pilots of the airline, which were very similar to the group of pilots who participated in the field study.

2.3. 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 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 whole measurement period, the pilots used a hand-held computer to rate their sleep-wake patterns and on-duty alertness levels and management strategies on a daily basis. The computerized questionnaire was tailored for each route and work schedule and included the Karolinska Sleepiness Scale (Åkerstedt and Gillberg, 1990) and a list of alertness management strategies (Anund et al., 2008). KSS ratings were given in 87% and 95% of all SH and LH flights, respectively. The questionnaire also logged current location (city), work hours (start and end time), naps (timing and duration), and alcohol and coffee consumption to be filled in at bedtime. Upon awakening, participants filled in items on sleep (timing, duration, and quality), and the use of sleep-promoting medication. In addition to filling in the self-report scales, each pilot used a wrist-worn actigraph (GENEActiv, © 2015 Activinsights Ltd.) 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. Eighty-six percent and 84% of the actigraph recordings preceding the SH and LH FDPs, respectively, were successful.

2.4. Dependent variables

2.4.1. Sleep-wake pattern

The primary outcomes of the sleep-wake pattern was the sleep-wake ratio (amount of sleep/amount of wakefulness). It was calculated for the flight duty days and covered the period from the beginning of the main sleep that preceded an FDP until the end of the FDP. The amount of sleep was calculated by summing the actigraphy-based total sleep time (TST) of the main sleep period and the diary-based self-estimate of the amount of nap sleep obtained before and during an FDP. The rest of the period was classified as wake.

The sleep-wake ratio was analysed as a continuous and dichotomous variable. In the latter, the criterion of a reduced sleep-wake ratio was set at $\leq$ 0.33, which means $\leq$ 6 h of sleep for 18 h of wakefulness. This means, for example, $\leq$ 6 h of sleep for 18 h of wakefulness, which is below the sleep-wake ratio proposed in the Flight and Duty Time regulations in the European Union (COMMISSION REGULATION (EU) No 83/2014). According to the regulations, sleep opportunities shorter than 8 h and periods of wakefulness exceeding 18 h should be avoided. The cut-off for the amount of sleep ($\leq$ 6 h) was also below the average daily sleep need (8 h 5 min) and the habitual sleep time (7 h 21 min) the airline pilots who participated in the field study reported in a questionnaire. In addition to the sleep and waking times, napping before FDPs and during controlled rest breaks while being on-board an aircraft was used to describe the sleep-wake pattern.

2.4.2. On-duty alertness

The primary outcomes of on-duty alertness were the mean KSS ratings calculated across five flight phases (blocks off (Boff), top