Recurrent On-Duty Sleepiness and Alertness Management Strategies in Long-Haul Airline Pilots

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INTRODUCTION: We examined whether long-haul airline pilots without recurrent on-duty sleepiness obtain more prior sleep and use more effective in-flight alertness management strategies than their colleagues with recurrent on-duty sleepiness.

METHODS: There were 51 pilots who flew at least twice from Helsinki to Asia. Of them, 44 flew at least twice back to Helsinki following 1 local night. On-duty sleepiness was measured by the Karolinska Sleepiness Scale (KSS), alertness management strategies by a diary, and sleep by a diary and activity monitor. Pilots who rated KSS $\geq$ 7 on each, some, or none of the flights were classified as ″regularly″, "sometimes", and "never" sleepy, respectively. This classification was performed separately for the outbound and inbound flights.

RESULTS: On the outbound flights, 22% of the pilots were "never", 54% "sometimes", and 24% "regularly" sleepy. For the inbound flights, the respective distribution was 25%, 48%, and 27%. Compared to the "regularly" sleepy group, the "never" sleepy group obtained 54 min more night sleep prior to the outbound flights. For the inbound flights, the respective difference was 1 h 23 min. Also, the "never" sleepy pilots slept 31 min more between days off than the ″regularly″ sleepy pilots. The results of the in-flight alertness management strategies were mixed.

DISCUSSION: The study demonstrates that pilots without recurrent on-duty sleepiness obtain more sleep than their colleagues with recurrent on-duty sleepiness. The result emphasizes the need to investigate whether the sleep of recurrently sleepy pilots can be increased and whether this increase would reduce their on-duty sleepiness.

KEYWORDS: airline pilots, sleepiness, sleep, alertness management, long-haul flights.

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On-duty sleepiness among airline pilots is a well-recognized safety hazard in aviation.[4,12] One of the most important factors underlying this hazard is airline pilots' irregular working hours, which often overlap with their circadian nadir of alertness.[10,22] This phenomenon particularly holds for long-haul (LH) flights that are also often characterized by curtailed prior sleep and flying an extended period of time without a stopover. On average, airline pilots report sleepiness on every second to fifth nighttime LH flight.[23]

A practically relevant question in this context is whether there are individual differences in pilots' sleepiness levels that are associated with ways in which they apply alertness management strategies. These strategies, such as preduty sleep and on-duty caffeine consumption, are modifiable and included in alertness management training provided to pilots under the safety management system of an airline.[8,9,14] However, empirical data on alertness management strategies that distinguish less sleepy pilots from their more sleepy counterparts may help further develop this kind of training and LH pilots' overall possibility of maintaining on-duty alertness. To the best of our knowledge, there are no such studies available, whereas trait-like individual differences in responses to sleep restriction are a widely examined topic.[26]

The aim of the present study was to examine the association between pilots' on-duty sleepiness and their strategies for maintaining alertness during nighttime LH flights. Our expectation was that, after controlling for pertinent individual and working

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hour characteristics, the pilots without recurrent on-duty sleepiness obtain more prior sleep and apply more effective in-flight alertness management strategies than their recurrently sleepy colleagues.

METHODS

Subject and Materials

The study protocol was approved in advance by the Ethics Committee of the Finnish Institute of Occupational Health. Each subject provided written informed consent before participating. The data of the present study was extracted from a large field and questionnaire data set collected as a part of a large-scale study on well-being at work among commercial airline pilots. The whole study has been described in detail in a previous report.[23]

The field and questionnaire data was originally collected from 58 pilots who flew LHs (scheduled flight time >6 h, operated by wide body aircrafts). There were 29 pilots who flew only LH routes and 29 who flew both LH and short-haul (scheduled flight time ≤6 h, operated by narrow body aircrafts) routes.

The only LH route suitable for the purpose of the present study was an outbound flight from Helsinki to Asia (afternoon-early evening departure) and back to Helsinki (early morning departure from Asia in Helsinki time), called hereafter the Helsinki-Asia-Helsinki route. To make the inbound flight duty periods (FDPs) comparable in terms of the number of nocturnal sleep opportunities in Asia and acclimatization status, only those inbound FPDs that were preceded by 1 local night were included in the analyses. The Asian destinations of the route were Bangkok (20% of 222 routes), Chongqing (4%), New Delhi (4%), Hanoi (1%), Hong Kong (1%), Krabi (1%), Nagoya 13%), Tokyo (13%), Osaka (9%), Peking (4%), Phuket (2%), Shanghai (12%), Seoul (13%), and Xian Xianyang (2%).

A total of 51 and 44 pilots had at least 2 successfully measured outbound and inbound flights of the Helsinki-Asia-Helsinki route, respectively. This number of flights per pilot was used as a criterion to study recurrent on-duty sleepiness (see below). The study was limited to the Helsinki-Asia-Helsinki routes only because of an insufficiency of data for the westward LH routes. Of the LH routes, 87% were to Asia and only 13% to the United States or Canada in the original data. Of the outbound flights ($N = 210$), 74% were 3-pilot and 26% 2-pilot operations. All the inbound flights that were included in the analyses were 3-pilot operations ($N = 143$).

Measures

Prior to the field measurements, the pilots filled in a questionnaire including items on age, sex, flying experience, family situation, overall health status ("How do you evaluate your health in relation to others comparable in age?"),[18] overall stress level,[7] weight, height, physical activity ("How much walking/brisk walking/jogging/brisk running did you, on average, have in your spare time or while commuting in the past year?"),[15] current smoking, weekly alcohol usage, diurnal type ("One hears about "morning" and "evening" types of people. Which one of these types do you consider yourself to be?"),[13] 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"), daily sleep need ("How many hours of sleep do you need in a day to be alert and in good shape at work the next day?"), insomnia on vacation ("How often have you had difficulties falling asleep/falling back asleep after waking up in the middle of the night/waking up? Assess your situation after a two-week vacation."), severe sleepiness on vacation ("How often have you had severe sleepiness while being awake? Assess your situation after a two-week vacation."), snoring ("Do you snore while sleeping? (ask other people if you are not sure)"),[19] and commuting time.

During the measurement periods that included both duty days and days off, the pilots used a tablet computer to report their sleep-wake patterns, on-duty sleepiness, and alertness management strategies on a daily basis. The questionnaire included the Karolinska Sleepiness Scale (KSS)[2] and a list of alertness management strategies.[3] KSS ratings were given at all phases of flight [blocks off (Boff), top of climb (ToC), cruise phase (CP), top of descent (ToD), blocks on (Bon)]. At CP, KSS was filled in in every 2 h. The in-flight alertness management strategies applied were reported at the end of each flight.

KSS ratings were given in 95% and 96% of all outbound and inbound flights of the Helsinki-Asia-Helsinki route, respectively. The location (city), work hours (start and end time), naps (timing and duration), and alcohol and coffee consumption were to be reported at bedtime. Upon awakening, subjects filled in items on sleep (timing, duration, and quality) and the use of sleep-promoting medication. In addition to the use of the self-report scales, each pilot wore an activity monitor on the wrist of the nondominant hand (GENEActiv©, 2015 Activinsights Ltd.) for collecting data on sleep quantity and quality over the measurement period. The pilots were instructed to press the event button of the activity monitor at lights out and when rising from bed at the end of the sleep period. Of the diary, 89% and 83% of the activity monitor recordings, respectively, were successful in connection with the Helsinki-Asia-Helsinki route. For the days off, the respective figures were 87% ($N = 3045$) and 82% ($N = 2897$).

The primary variables used to assess sleep-wake behaviors were the amount of activity-based sleep obtained during the main sleep period and the sleep-wake ratio calculated for the period between the start of the main sleep prior to an FDP and the end of that FDP. In addition, the amount of diary-based nap sleep during the flights and in spare time, and total sleep duration (main+nap sleep) were used. Sleep quality was estimated by activity-based sleep efficiency and diary-based overall estimation of sleep (How well did you sleep?). All sleep variables were studied separately for the days of the outbound and inbound flights and the days off. In addition to the above-mentioned in-flight strategic nap sleep, the variables of in-flight alertness management strategies were taking a rest break (without sleeping), using alertness-promoting products (coffee, energy drinks, and nicotine-containing snuff), and/or activity (e.g., moving the body).

The variable to indicate sleepiness level during a flight was the highest KSS rating given during that flight. When the highest rating was 7 or higher the pilot was considered to have been sleepy on that flight. KSS ratings 7 or higher have been shown to coincide with increases in physiological and behavioral signs of lowered alertness.[1] Each pilot's disposition toward recurrent on-duty sleepiness was assessed separately for the outbound and inbound flights. When a pilot rated 7 or higher on the KSS on each of his outbound flights he was classified as a "regularly" sleepy pilot. When a pilot rated 7 or higher on none of the outbound flights he was considered to belong to the category of "never" sleepy pilots. Finally, when a pilot rated 7 or higher on some (but not all) of his outbound flights he was classified as a "sometimes" sleepy pilot. The same classification was applied to the inbound flights, too. To belong to one of these three sleepiness groups, a pilot had to have at least two successfully measured outbound/inbound flights because otherwise the pilot could not have fallen into the "sometimes" sleepy group.

Statistical Analysis

Differences between the sleepiness groups were tested separately for the outbound and inbound flights. In both cases, multinomial logistic regression and Chi-squared tests were used to compare the sleepiness groups with respect to the categorical outcomes, and an analysis of variance (glm procedure) to compare the groups with respect to the continous outcomes. In both types of analyses, the statistical models were run without (crude model) and with age as a covariate (adjusted model). Planned pairwise comparisons between the never sleepy group and the two other sleepiness groups were run when the main effect reached statistical significance in the adjusted model. The selection of covariates was based on the comparison of the sleepiness groups in terms of work-related, individual-related, and sleep-related factors (see auxiliary **Table A**, found online at https://doi.org/amhp.5092sd.2018). Alpha was set at 0.05 for all analyses. The analyses were carried out using the SAS 9.4. software package.

RESULTS

Of the pilots on the outbound flights ($N = 11$), 22% fell into the "never" sleepy group and 54% ($N = 28$) and 24% ($N = 12$) into the "sometimes" and "regularly" sleepy groups, respectively. For the inbound flights, the respective distribution was 25% ($N = 11$), 48% ($N = 21$), and 27% ($N = 12$). The number of flights per pilot in the sleepiness groups of the outbound flights was 3.1 (SD 1.4) for the "never" sleepy group and 4.4 (SD 0.7) and 4.3 (SD 0.7) for "sometimes" and "regularly" sleepy groups, respectively. For the sleepiness groups of the inbound flights, the respective figures were 2.8 (SD 0.7), 3.5 (SD 0.7), and 3.3 (SD 0.7).

Of the 11 "never" sleepy pilots of the outbound flights, 1 stayed in the same sleepiness group during the inbound flights and 4 shifted to the "sometimes" sleepy and 1 to the "regularly" sleepy group. Five of the pilots had fewer than two successfully measured inbound flights. Of the 12 "regularly" sleepy pilots of the outbound flights, 7 stayed in the same sleepiness group during the inbound flights and 2 shifted to the "sometimes" sleepy group and 3 had fewer than 2 successfully measured inbound flights.

The sleepiness groups of the outbound flights differed in terms of age, flying experience, and self-estimated habitual sleep length (Table A in auxiliary material). The planned pairwise tests showed that the "never" sleepy pilots were, on average, 7.1 yr older ($t = 2.77$, $P = 0.0079$) and had 6.6 yr more flying experience ($t = 2.38$, $P = 0.0215$) than their "regularly" sleepy counterparts. The paired comparisons between the "never" and "sometimes" sleepy pilots did not yield significant findings. The sleepiness groups of the inbound flights showed no differences in any of the individual-related or sleep-related characteristics studied (Table A in auxiliary material).

The outbound FDPs started at 1628 (SD 52 min) and ended at 0314 (SD 49 min) in Helsinki time. The mean duration of the outbound FDPs was 10 h 46 min (SD 54 min). The pilots had, on average, 101 h 23 min (SD 61 min) free time before the start of the outbound FDPs. The three sleepiness groups of the outbound FDPs did not differ in any of these FDP characteristics.

The inbound FDPs started at 0345 (SD 31 min) and ended at 1526 (SD 44 min) in Helsinki time. The mean duration of the inbound FDPs was 11 h 41 min (SD 43). The pilots had, on average, 24 h 32 min (SD 41 min) free time before their inbound FDPs. The time difference between the homebase and the destinations varied between 3.5 and 7 h, with its median being 6 h. The three sleepiness groups of the inbound FDPs did not differ in any of these FDP characteristics.

Fig. 1 shows the course of the mean KSS ratings over the outbound and inbound flights in the three sleepiness groups. For the outbound flights, the mean KSS ratings of the sleepiness groups across the flight phases differed significantly ($F = 26.12$, $P < 0.0001$). The ratings of the "never" sleepy pilots were, on average, 0.3 steps ($t = 2.27$, $P = 0.0245$) and 1.0 step ($t = 6.38$, $P < 0.0001$) lower as compared to the "sometimes" and "regularly" sleepy pilots, respectively. The group difference reached its maximum between the middle and last part of the flight (CP-Bon).

The sleepiness groups of the inbound flights differed significantly in the mean KSS ratings across the flight phases ($F = 29.06$, $P < 0.0001$). The ratings of the "never" sleepy pilots were, on average, 0.8 steps ($t = 4.63$, $P = 0.0001$) and 1.4 steps ($t = 7.28$, $P < 0.0001$) lower as compared to their "sometimes" and "regularly" sleepy counterparts, respectively. The group difference reached its maximum during the first part of the flight (Boff-ToC).

The sleepiness groups of the outbound flights differed in rise time, main sleep length and efficiency, in-flight nap sleep length, total sleep duration (main+nap sleep), and the sleep-wake ratio in their outbound flight days (Table I). The amount of main and total sleep were significantly greater for the "never" sleepy than the "regularly" sleepy pilots, the mean differences being 54 min and 46 min, respectively. Also, the sleep-wake

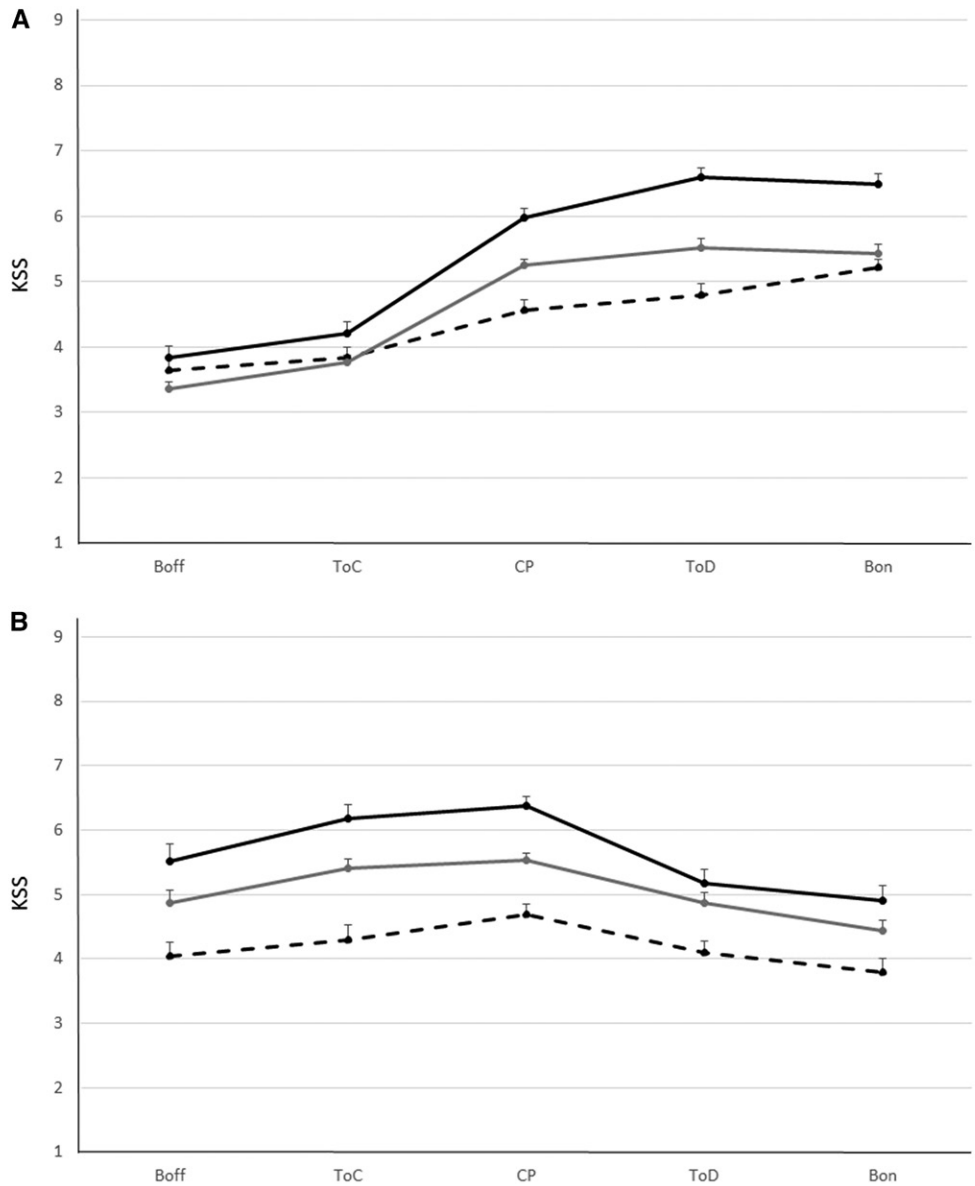

Fig. 1. Self-rated [Karolinska Sleepiness Scale (KSS): 1 = extremely alert; 9 = very sleepy] sleepiness over the phases of the A) outbound and B) inbound flights of the Helsinki-Asia-Helsinki route in the three sleepiness groups (never: dotted black line; sometimes: solid gray line; regularly sleepy: solid black line). Boff = Blocks off, ToC = Top of Climb, CP = Cruise Phase, ToD = Top of Descent, Bon = Blocks on. The vertical lines denote SEMs (standard error of the mean).

ratio was significantly greater for the "never" sleepy than for the "regularly" sleepy pilots. The "never" and "sometimes" sleepy groups did not significantly differ in these outcomes.

The sleepiness groups of the inbound flights showed differences in bedtime, main sleep length and efficiency, total sleep duration (main+nap sleep), and the sleep-wake ratio in their inbound flight days (**Table I**). The "never" sleepy pilots went to bed, on average, 65 min earlier than the "regularly" sleepy pilots. The amount of main and total sleep was significantly greater for the "never" sleepy group than the "sometimes" (mean difference 42 min and 45 min, respectively) and "regularly" sleepy (mean difference 1 h 27 min and 1 h 23 min, respectively) groups. Also, the sleep/wake ratio and main sleep efficiency were higher for the "never" sleepy pilots than for the "sometimes" sleepy and the "regularly" sleepy groups.

The sleepiness groups of the outbound flights differed in terms of bedtime, rise time, time in bed, sleep length, sleep efficiency, and subjective sleep quality between the days off (**Table II**). The "never" sleepy pilots went to bed, on average, 23 min and 31 min later and got up, on average, 23 min and 42 min later than the "sometimes" and "regularly" sleepy pilots, respectively. The main sleep length of the "never" sleepy pilots was, on average, 10 min and 37 min longer as compared to the "sometimes" and "regularly" sleepy pilots, respectively. Activity-based sleep efficiency was 4%-points higher for the "never" sleepy pilots than for the "regularly" sleepy pilots, but their self-rated sleep quality was more frequently poor as compared to the "sometimes" sleepy pilots.

The sleepiness groups of the inbound flights differed only in terms of main sleep efficiency and subjective quality between the days off (Table II). Activity-based sleep efficiency was 3%-points higher for the "never" sleepy group as compared to the two other groups. The proportion of the main sleep periods with poor self-rated quality was 3%-points and 8%-points lower for the "never" sleepy pilots than for the "sometimes" and "regularly" sleepy pilots, respectively.

The sleepiness groups differed in terms of taking rest breaks (without sleep) and being engaged in alertness promoting activity during the outbound flights (**Table III**). The "never" sleepy pilots reported less frequent alertness-promoting activity than the "regularly" sleepy pilots, but more frequent rest breaks than the "sometimes" sleepy pilots. The sleepiness groups showed differences only in consumption of alertness-promoting products (Table III). The "never" sleepy group reported consumption more frequently than the two other groups.

DISCUSSION

Our field study shows that there is an association between recurrent on-duty sleepiness and the amount of sleep prior to a

Table I. Sleep-Wake Behaviors of the Three Sleepiness Groups in Connection with the Helsinki-Asia-Helsinki Route.

	OUTBOUND FLIGHTS					INBOUND FLIGHTS				
	NEVER	**SOMETIMES**	**REGULARLY**	**CRUDE *P***	**ADJUSTED *P***	**NEVER**	**SOMETIMES**	**REGULARLY**	**CRUDE *P***	**ADJUSTED *P***
Bedtime, h:min (h)	23:43 (0.25)	23:48 (0.13)	23:35 (0.20)	0.6634	0.6598	18:44 (0.24)	19:13 (0.21)	19:49 (0.30)	0.0449	0.0349‡
Rise time, h:min (h)	8:45 (0.29)	8:19 (0.13)	7:59 (0.16)	0.0049	0.0493‡	1:14 (0.15)	1:20 (0.07)	1:23 (0.11)	0.6723	0.7263
Time in bed (main sleep), h	9.04 (0.27)	8.52 (0.12)	8.40 (0.16)	0.0678	0.2052	6.50 (0.27)	6.12 (0.20)	5.57 (0.27)	0.0708	0.1589
Main sleep length prior to FDP, h	7.96 (0.23)	7.43 (0.11)	7.06 (0.16)	0.0049	0.0112‡	5.70 (0.28)	5.00 (0.19)	4.25 (0.26)	0.0021	0.0045*,‡
% of FDPs with prior nap	9	15	15	0.6538	0.5954	3	3	0	0.9916	0.9900
Nap length prior to FDP, h	0.30 (0.17)	0.34 (0.07)	0.55 (0.13)	0.3019	0.3036	0.63 (-)	0.9 (0.4)	-	0.2265	0.2480
% of FDPs with a nap break	88.2	87.1	78.9	0.3289	0.1886	90.3	97.2	95.1	0.3709	0.3630
Nap sleep length during FDP, h	0.38 (0.05)	0.57 (0.04)	0.39 (0.05)	0.0098	0.0123*	0.82 (0.08)	0.81 (0.06)	0.92 (0.08)	0.4928	0.5756
Total sleep length at FDP end, h	8.34 (0.22)	8.06 (0.11)	7.58 (0.16)	0.0135	0.0189‡	6.57 (0.27)	5.82 (0.18)	5.18 (0.24)	0.0018	0.0034*,‡
Time awake until FDP end, h	17.90 (0.32)	18.38 (0.14)	18.60 (0.17)	0.1246	0.1418	13.45 (0.20)	13.35 (0.10)	12.93 (0.14)	0.0374	0.0628
Sleep/Wake ratio at FDP end	0.47 (0.02)	0.44 (0.01)	0.41 (0.01)	0.0029	0.0044‡	0.50 (0.03)	0.43 (0.01)	0.40 (0.02)	0.0059	0.0093*,‡
Main sleep efficiency, %	86 (1)	87 (1)	84 (1)	0.0447	0.0434	88 (1)	81 (2)	76 (2)	0.0018	0.0015*,‡
Poor subj. sleep quality, %	18	16	19	0.8803	0.7470	33	41	44	0.7225	0.6390

All clock times are in Helsinki time. FDP = flight duty period. The standard error of the mean is presented in hours in parentheses where appropriate. Never = "never" sleepy group; Sometimes = "sometimes" sleepy group; Regularly = "regularly" sleepy group; Crude = nonadjusted model; Adjusted = age-adjusted model.
* = Never vs. sometimes sleepy, $P < 0.05$; ‡ = never vs. regularly sleepy, $P < 0.05$.

flight: the pilots without recurrent on-duty sleepiness obtained more prior sleep than their colleagues with recurrent on-duty sleepiness. Less consistent evidence was found for the association between recurrent on-duty sleepiness and the use of in-flight alertness management strategies.

One of the most interesting results of the present study is the differences in the amount of prior sleep between the sleepiness groups after taking into account possible differences in the pertinent individual-related and working hour-related factors. The "never" sleepy pilots obtained, on average, 54 min–1 h 27 min more sleep, depending on the direction of the flight, than the "regularly" sleepy pilots. The "sometimes" sleepy pilots fell between these two extremes. In addition to quantity, the main sleeps of the sleepiness groups prior to the flights also differed in activity-based sleep efficiency. The results were better for the "never" sleepy group as compared to the two other groups (especially) prior to the inbound flights. The strategic in-flight naps did not significantly reduce the group differences observed in prior sleep, as demonstrated by the results of the total sleep time (main + nap sleep) and sleep-wake ratio.

An important question is whether the differences in prior sleep could explain the differences in recurrent on-duty sleepiness. A study on long haul airline pilots by Gander and colleagues[10] gives some support for an affirmative answer. The authors found that a 1-h increase in the amount of sleep in the 24 h prior to duty start was associated with improved on-duty

Table II. Main Sleep of the Three Sleepiness Groups Between Days Off.

	OUTBOUND FLIGHTS					INBOUND FLIGHTS				
	NEVER	**SOMETIMES**	**REGULARLY**	**CRUDE *P***	**ADJUSTED *P***	**NEVER**	**SOMETIMES**	**REGULARLY**	**CRUDE *P***	**ADJUSTED *P***
Bedtime, h:min (h)	01:07 (0.17)	00:44 (0.10)	00:36 (0.14)	0.0516	0.0449*,‡	00:41 (0.15)	00:47 (0.11)	00:35 (0.14)	0.5602	0.4671
Rise time, h:min (h)	09:01 (0.15)	08:38 (0.08)	08:19 (0.10)	0.0005	<0.0001*,‡	08:25 (0.13)	08:40 (0.09)	08:29 (0.11)	0.2260	0.1791
Time in bed, h	8.12 (0.10)	7.96 (0.06)	7.73 (0.09)	0.0117	<0.0033‡	7.79 (0.10)	7.99 (0.07)	7.89 (0.09)	0.2388	0.2402
Main sleep length, h	7.13 (0.09)	6.97 (0.06)	6.51 (0.09)	<0.0001	<0.0001*,‡	6.94 (0.09)	6.88 (0.07)	6.80 (0.09)	0.5270	0.2899
Main sleep efficiency, %	88 (0.3)	87 (0.3)	84 (0.4)	<0.0001	<0.0001‡	89 (0.3)	86 (0.4)	86 (0.4)	<0.0001	<0.0001*,‡
Poor subj. sleep quality, %	22	14	17	0.0067	0.0405*	12	15	20	0.0161	0.0059*,‡

In the adjusted model, age has been used as a covariate. The standard error of the mean is presented in hours in parentheses where appropriate. All clock times are in Helsinki time. Never = "never" sleepy group; Sometimes = "sometimes" sleepy group; Regularly = "regularly" sleepy group; Crude = nonadjusted model; Adjusted = age-adjusted model.
* = Never vs. sometimes sleepy, $P < 0.05$; ‡ = never vs. regularly sleepy, $P < 0.05$.

Table III. In-Flight Alertness Management Strategies of the Three Sleepiness Groups in the Helsinki-Asia-Helsinki Route.

	OUTBOUND FLIGHTS					INBOUND FLIGHTS				
	NEVER	SOMETIMES	REGULARLY	CRUDE *P*	ADJUSTED *P*	NEVER	SOMETIMES	REGULARLY	CRUDE *P*	ADJUSTED *P*
Rest break without sleep, % of flights	21	11	23	0.0749	0.0200*	*19*	*18*	*29*	0.3820	0.7188
Alertness-promoting products, % of flights	44	68	58	0.0387	0.0866	*94*	*65*	*71*	0.0278	0.0286*,ǂ
Alertness-promoting activity, % of flights	53	55	79	0.0099	0.0135ǂ	*77*	*65*	*76*	0.3133	0.3436

In the adjusted model, age has been used as a covariate. Never = "never" sleepy group; Sometimes = "sometimes" sleepy group; Regularly = "regularly" sleepy group; Crude = nonadjusted model; Adjusted = age-adjusted model.
* = Never vs. sometimes sleepy, $P < 0.05$; ǂ = never vs. regularly sleepy, $P < 0.05$.

alertness. In line with these results, a naturalistic field study on commercial truck drivers found that a 2 to 3-h difference in the amount of prior sleep was associated with the occurrence of a safety-critical event during the ensuing shift.[5] Also, our previous study on train drivers and rail traffic controllers showed that each additional hour of sleep prior to a shift decreased the risk of on-duty sleepiness by 15%.[11] In light of these findings it seems likely that the observed difference in the amount of prior sleep between the sleepiness groups can at least partly explain why some pilots experienced recurrent sleepiness on board while some others did not.

The sleep of the sleepiness groups of the outbound flights differed not only prior to the flights, but also on days off. This finding was in line with the observed difference in self-reported habitual sleep length between the sleepiness groups. The sleepiness groups did not, however, differ in their self-assessed daily sleep need. Together these findings propose that the pilots without recurrent on-duty sleepiness were less likely to be under cumulative sleep restriction than their counterparts with frequent such experiences. Thus, it can be assumed that it was not only the amount of sleep immediately before the flight that played a role, but also the fact that the pilots without recurrent on-duty sleepiness also slept more on their days off, making them less vulnerable to the tiring characteristics of the outbound flights.

As opposed to the sleepiness groups of the outbound flights, the sleepiness groups of the inbound flights did not differ significantly in their sleep length on days off. A reason for this difference probably is that sleep prior to the outbound flights represents a normal night's sleep, whereas sleep prior to the inbound flights was restricted by the early start of the FDP in Helsinki time. A recent study by Cosgrave and colleagues also found that pilots' sleep prior to transmeridian inbound flights was limited when the start time of duty did not provide them with a full sleep opportunity during their biological night.[6]

A significant practical question arising from our findings is whether pilots with recurrent sleepiness would actually be able to sleep more prior to their flights. Previous research does not provide much evidence for the idea that, in general, shift workers can easily change their sleep-wake patterns. A recent systematic review concluded that the current research does not allow one to determine whether shift workers' alertness, sleep length, or sleep quality can be significantly improved through nonpharmacological interventions.[25] Also, the result of systematic interindividual differences in sleep response to shift work supports the idea that shift workers' sleep-wake patterns are quite stable.[16] On the other hand, sleep-wake behaviors are modifiable by nature, but within certain limits, like health behaviors as a whole. A promising option to help recurrently sleepy pilots sleep 1–2 h more prior to LH flights is to carry out interventions in a personalized and context-specific manner using mobile health technology.[17,28]

The results of the in-flight alertness management remained less clear than those of prior sleep. The sleepiness groups of both the outbound and inbound flights differed in terms of the use of alertness promoting products, but in the opposite direction. During the outbound flights, the "never" sleepy pilots tended to report less frequent use of these products than the other pilots, whereas during the inbound flights the pattern was reversed. Secondly, the "sometimes" sleepy pilots of the outbound flight obtained, on average, 11 min more sleep than the other two sleepiness groups, whereas during the inbound flights the groups showed no difference.

In summary, our results suggest that the association between recurrent on-duty sleepiness and the in-flight alertness management strategies is not systematic. However, there are a few reservations to this suggestion. In the present study, all in-flight strategies were reported only at the end of the flight, except for strategic naps that were logged immediately after each nap period. In addition, no data on the extent of the use of alertness-promoting activities, products, and rest breaks (without sleep) were collected, but only data of whether or not a pilot reported having applied these strategies. These methodological issues make it difficult to draw definite conclusions from the association between on-duty sleepiness and in-flight alertness management strategies.

A previous study on long haul truck drivers showed that the drivers applied efficient alertness management strategies (caffeine consumption and/or napping) more frequently on night than nonnight shifts, indicating that the drivers adequately responded to increased sleepiness.[21] This result, as opposed to those obtained in the present study, proposes that that the association between on-duty sleepiness and the use of sleepiness countermeasures exists. It is, however, noteworthy that the truck driver study compared two different types of work shifts using the same individuals, whereas the present study compared different individuals using similar work shifts. In addition, the truck drivers did not have any standard procedure for taking a nap break, whereas the pilots had such a procedure.

It is also important to note that our mixed results on the association between in-flight alertness management strategies and recurrent on-duty sleepiness does not imply that these strategies would not be beneficial. There are experimental studies showing that both caffeinated products and nap breaks are beneficial when driving or working at night.[20,24]

The results of sleep and in-flight alertness management strategies discussed above are based on our classification of pilots into the three sleepiness groups. Approximately one-fourth of the pilots rated themselves sleepy either during none or each of the nighttime outbound flights and one-half during some of them. A similar result was found for the inbound flights with early morning departure (Helsinki time) from Asia.

Our findings of subjective sleepiness across the outbound and inbound flights demonstrate that the sleepiness groups did not only differ in their peak sleepiness but also in average sleepiness across the flight phases. This finding shows that the sleepiness groups differed quite consistently in the expected direction with respect to their sleepiness levels across the flights and thus emphasizes the fact that the group differences in sleepiness were significant. Also, the differences in sleepiness patterns varied in the expected manner between the outbound and inbound flights. For the outbound flights, sleepiness peaked during the latter part of the flight, while the opposite pattern was true for the inbound flights. The reason is, very likely, that the outbound and inbound flights differed in the timing of the circadian nadir of alertness. For the former, the circadian nadir is likely to occur during the latter part of the flight, as the pilots can be expected to be acclimatized to the local time of their homebase. For the latter, the circadian nadir can be expected to occur during the early part of the flight (early morning hours at their homebase), as the short, 24-h layover significantly limits acclimatization to the local time of an Asian destination.

In all, our results are in line with two previous studies by Lammers van der Holst and colleagues[16] and Van Dongen and colleagues[27] in suggesting that systematic individual differences can also be found in highly selected occupational groups in response to tiring job characteristics. However, some caution should be exercised when interpreting the results because the number of subjects and flights per pilot were somewhat low. Further research with more subjects and flights per pilot are needed to confirm our main results. These increases in the amount of data would also allow one to have better control over pertinent long-lasting and even trait-like individual differences, such as diurnal type, sleep disturbances, and sensitivity to sleep restriction, when examining the role of alertness management strategies. In addition, the role of age remains open in the present study. The never sleepy pilots of the outbound flights were significantly older than their regularly sleepy counterparts. There are many possible explanations for this finding, such as the healthy worker effect and life situations in general, but a more comprehensive data than the present one are needed to confirm and explain the finding.

The main strengths of the present study are a naturalistic approach and the fact that the same airline pilots flew very similar long-haul routes more than once, making it possible to assess their predisposition to experience sleepiness while on duty. In addition, the background information of the pilots and the field measurements were quite comprehensive. The main limitations of the study have already been discussed above, such as the rather low number of pilots and flights per pilot, but it is worth adding that our results are based on only one type of LH route. This leaves it open whether the results apply to other types of routes, too. Moreover, the number of flights per pilot was approximately one lower in the "never sleepy" group than the "sometimes sleepy" group. This difference makes the likelihood of becoming classified as "sometimes" sleepy or "never" sleepy somewhat uneven for these groups.

To conclude, the LH airline pilots without recurrent on-duty sleepiness obtain more prior sleep than their colleagues with recurrent on-duty sleepiness. This finding emphasizes the need to study whether the sleep of long-haul pilots with recurrent on-duty sleepiness can be increased by nonpharmacological interventions and, secondly, whether this increase would actually reduce their on-duty sleepiness.

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