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AVIATION, SPACE & ENVIRONMENTAL MEDICINE

Age, Circadian Rhythms, and Sleep Loss in Flight Crews

PHILIPPA H. GANDER, Ph.D., DE NGUYEN, B.E., MARK R. ROSEKIND, Ph.D., and LINDA J. CONNELL, M.A.

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Age-related changes in trip-induced sleep loss, personality (n = 205), and the pre-duty temperature rhythm (n = 91) were analyzed in crews from various flight operations. Eveningness decreased with age (subjects aged 20–30 were more evening-type than subjects over 40). The minimum of the baseline temperature rhythm occurred earlier with age (earlier in subjects aged 30–50 than in subjects aged 20–30). The amplitude of the baseline temperature rhythm declined with age (greater in subjects aged 20–30 than in subjects over 40). Average daily percentage sleep loss during trips increased with age. Among crewmembers flying longhaul flight operations, subjects aged 50–60 averaged 3.5 times more sleep loss per day than subjects aged 20–30. These studies support previous findings that evening types and subjects with later peaking temperature rhythms adapt better to shift work and time zone changes. Age and circadian type may be important considerations for duty schedules and fatigue countermeasures.

FATIGUE, SLEEPINESS, and circadian rhythms can have critical effects on safety margins in aviation. Analyses of confidential reports to the NASA Aviation Safety Reporting System indicate that about 21% of all reported incidents are fatigue-related (20). Such incidents tend to occur more frequently in the early hours of the morning, and are often potentially serious. In a 1989 Safety Recommendation (26), the National Transportation Safety Board reviewed a number of major transportation accidents which they concluded "raise serious concerns about the far-reaching effects of fatigue, sleepiness, sleep disorders and circadian factors in transportation system safety."

From the San Jose State University Foundation at NASA-Ames (P. H. Gander and D. Nguyen) and NASA-Ames Research Center, Moffett Field, CA (M. R. Rosekind and L. J. Connell).

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Address reprint requests to Philippa H. Gander, Ph.D., who is Principal Scientist, San Jose State University Foundation at NASA-Ames Research Center, Flight Human Factors Branch, MS 262-4, Moffett Field, CA 94035.

Laboratory experiments and studies of shiftwork in other sectors have identified age-related changes in sleep and the circadian system which might be expected to affect the ability of flight crewmembers to adapt to duty demands. With normal aging, nighttime sleep becomes shorter, lighter and more disturbed (with more awakenings and transient arousals), and daytime sleepiness increases (2). In effect, there is a reduction in the amplitude of the sleep/wake cycle (less sleep at night, more sleepiness during the day), which may be part of a more general phenomenon of reduction in the amplitude of circadian rhythms with increasing age (2,3,4,25,31,32). It has been suggested that the age-related decrease in the amplitude of the oral temperature rhythm may be related to greater intolerance to shift work (27).

There is also evidence that the circadian system may develop an earlier phase position with respect to the day/night cycle as one gets older. Earlier bedtimes and awakening times are commonly reported in surveys of the sleep patterns of elderly people (2). Rapid-Eye-Movement (REM) sleep, which is the stage of sleep associated with dreaming, occurs earlier in the nighttime sleep of older subjects. The circadian rhythms of cortisol, temperature, thyroid stimulating hormone and lymphocytes have also been reported to peak and/or trough earlier in the day with increasing age (2,3,33). If this phenomenon is robust, it might be expected to slow the rate of circadian readaptation of older subjects after time zone crossings and schedule changes. Colquhoun (7) has reported that subjects with late-peaking temperature rhythms adjusted more rapidly to an 8-h eastward transmeridian flight than subjects with early-peaking temperature rhythms.

The circadian type questionnaire of Horne and Ostberg (22) differentiates "evening types" and "morning types," and subjects in the two extremes of the classification differ in sleep timing and in the time of day of the circadian temperature maximum (e.g., 7). It has been suggested that people may become more morning

type with increasing age (24). A number of shiftwork studies (1,15,21,23,24) have indicated that evening-types adapt better to shift work than morning-types. In a group of commercial longhaul flight crewmembers, Sasaki et al. (29) found that evening-types showed lower levels of daytime sleepiness after an 8 h eastward flight than morning-types.

Individual differences in adaptation to time zone crossings and schedule shifts have also been correlated with scores on the Eysenck Personality Inventory (14). There is some evidence that individuals who score high on the extraversion and neuroticism scales may adapt more rapidly than other personality types to time-zone and schedule changes (8). In a group of Norwegian Air Force flight crewmembers, subjects with higher extraversion scores also showed larger phase delays in their rectal temperature rhythms 5 d after a 9-h westward time-zone transition (16).

Beginning in the early 1980's, the Fatigue Countermeasures Program at NASA-Ames Research Center has undertaken extensive field studies to investigate fatigue, sleep, and circadian rhythm disruption in a variety of aviation operations (9–11,16–19,28,30). These studies provide a rich data set for the study of age-related changes in sleep loss, circadian rhythms, and personality. The sample size is large and includes the complete range from 20 to 60 years of age. Most studies compare groups of young and old subjects, and very few include groups of intermediate age (3). Physiological data were recorded continuously and, therefore, circadian rhythms can be characterized. Because the data were collected in uncontrolled field conditions, it is possible to look for age-related changes in the circadian system in subjects pursuing their normal activities, as opposed to in laboratory situations. In addition, each subject completed the Morning/Eveningness Questionnaire and the Eysenck Personality Inventory. Daily sleep loss was measured during scheduled flight operations, and is, therefore, directly relevant to concerns about the effects of fatigue on flight safety. The initial focus of the present study was to determine if age-related changes in sleep and circadian rhythm parameters could be detected in these field data. Subsequent analyses examined the influence of such changes, and of personality, on sleep loss during flight operations.

METHODS

All subjects volunteered to be monitored for at least one day before a scheduled line of flying, throughout the trip (accompanied by a NASA cockpit observer) and for several days after their return home. Commercial longhaul flight crews had at least 4 d without time zone changes before entering the study (18). Throughout their participation, subjects wore a portable biomedical monitor (Vitalog PMS-8, Vitalog Corporation, Redwood City, CA) which recorded 2-min averages of heart rate and non-dominant wrist activity and 2-min measurements of rectal temperature. Sleep timing and quality, and the timing of naps, were recorded in a daily log book. Subjects also completed a background questionnaire which included the Morningness/Eveningness Questionnaire (22), and the Eysenck Personality Inventory (14). In addition, NASA cockpit observers kept detailed records of operational events and conditions. A complete description of these measures is available elsewhere (17).

Six different categories of operations were analyzed (Table I). Commercial shorthaul trips lasted 3–4 d with up to 8 short flight segments per day, primarily during daylight hours and with a maximum time zone change per day of 1 h. Overnight cargo trips were up to 8 d long with up to 6 segments per duty day, primarily flying at night, and with a maximum time zone change per day of 1 h. Military medical evacuation trips lasted 4 d with multiple flight segments per day, including both day and night flights, and with a maximum time zone change of 2 h/d. Commercial longhaul and C-141 military longhaul trips were up to 9 d long and included sequences of long transoceanic flights, usually crossing many time zones (alternating eastward and westward flights), with irregular hours of work and rest. The C-130 operations involved deployments (maximum duration 10 d) from Texas to either England or Turkey, followed by several days of shorthaul-type flying at the destination, and then return. A number of publications are available on these different types of operations (9–11,16–19,30), and analyses of these databases are on-going.

Cumulative sleep loss was calculated for each subject as the sum across the trip of the number of hours of sleep (including naps) lost or gained in each 24 h, relative to his or her baseline sleep duration (including naps). This total was converted to a mean daily percentage of the baseline sleep duration.

The characteristics of the baseline temperature rhythm (minimum, maximum, amplitude) were estimated by applying a locally weighted regression smoothing (6) to the temperature data averaged in 20 min bins (3 iterations with delta = 1% of the range). This technique was chosen to reduce the effects of local noise on these estimates, and was preferred to sinusoid

TABLE I. BREAKDOWN OF DATA ANALYZED.

Type of operation	Aircraft type	No. of subjects	Mean age	S.D. age
Commercial shorthaul	B-737, DC-9	67 (16)	42 (38)	7.8 (6.6)
Commercial longhaul	B-747 series†	26 (10)	53 (51)	4.9 (5.3)
Commercial overnight cargo	B-727	39 (24)	38 (37)	5.3 (4.8)
Military medical evacuation	C-9	13 (5)	29 (30)	5.1 (4.5)
Military longhaul/shorthaul	C-130	19 (15)	27 (27)	3.0 (3.2)
Military longhaul	C-141	41 (21)	29 (30)	6.7 (8.0)

* Total n = 205 (91). The first value is for personality and sleep loss data. Value in parentheses is the subset of subjects who gave complete temperature data.

fitting as it makes no assumptions about the shape of the waveform. The temperature minimum was selected as the circadian phase marker since, as expected in subjects synchronized to their home time zone, it occurred during sleep and was, therefore, minimally influenced by individual differences in levels of physical activity during wake.

Data on mean daily percentage sleep loss, personality, and age were available for 205 subjects. At least one full cycle (24 h) of baseline temperature data were available for 91 (44%) of these subjects (Table I).

One-way analysis of variance (ANOVA) was used to test for differences among different types of flight operations, and among age groups. For the latter analyses, the data set was divided into 10-year age categories (20–30, 30–40, 40–50, and 50–60). When significant differences were found, Tukey post hoc tests with Bonferroni correction were used to compare each category with every other category.

All-possible-subsets regression and stepwise regression analyses were carried out to examine which of the following variables contributed most to the variance in average daily percentage sleep loss: age, extraversion, neuroticism, morning/eveningness, local time of sleep onset, local time of the baseline temperature minimum, and amplitude of the baseline temperature rhythm.

RESULTS

Age Differences Among Subject Groups From Different Flight Operations

One-way ANOVA indicated that the age of subjects differed significantly ($F = 63.43$, $p < 0.0001$) between the different types of flight operations (as defined in Table I). The flight crewmembers in each type of military flight operation were younger ($p < 0.01$ in each comparison) than flight crewmembers in any of the commercial operations, but not significantly different from each other. The commercial longhaul flight crewmembers were older ($p < 0.01$ in each comparison) than any other group, and the commercial shorthaul flight crewmembers and overnight cargo flight crewmembers were different in age from each other and all other groups ($p < 0.01$ in each comparison). Thus, except among the military flight crews, the age ranges were essentially nonoverlapping. It was, therefore, not possible to perform a 2-way ANOVA to compare simultaneously the effects of age and type of flight operations on sleep loss.

This problem was addressed in two ways. First, daily percentage sleep loss was compared among the different military flight operations (Table I), where the subject pools were not significantly different in age. These operations can be roughly classified (see Methods) as: shorthaul, including day and night flying (C-9); longhaul (C-141); and mixed longhaul and shorthaul (C-130). One-way ANOVA indicated no significant differences in average daily percentage sleep loss between these different types of flight operations ($F = 1.73$, $p = 0.17$). Second, the data sets for military longhaul (C-141) and commercial longhaul flight operations were combined, since these operations were of comparable duration and both included sequences of long trans-oceanic flights, usually crossing many time zones. This sub-population of longhaul flight crewmembers ($n = 67$) had a mean age of 38.3 years (s.d. 13.0), with a range from 20 to 60 years. It was thus possible to examine age-related changes in adaptation to a specific type of flight operations; i.e., longhaul.

Age-Related Changes

When all 205 subjects were considered in 1-way ANOVAs (Table II), subjects aged 20–30 scored significantly higher on the extraversion scale ($p < 0.05$) than subjects aged 30–40. Subjects aged 20–30 also scored significantly lower on the morning/eveningness questionnaire (i.e., were more evening-type) than subjects aged 40–50 ($p < 0.05$), and subjects aged 50–60 ($p <$

TABLE II. COMPARISON OF PERSONALITY AND SLEEP LOSS MEASURES (MEAN ± S.E.) ACROSS THE DECADES FROM 20 YEARS TO 60 YEARS OF AGE.

Personality and sleep loss measures	Age (years) 20–30	30–40	40–50	50–60
A. All crews (n = 205)				
Extraversion	7.97 (0.49)	5.69 (0.60)	7.04 (0.58)	7.08 (0.89)
Neuroticism	11.95 (0.48)	11.32 (0.47)	10.82 (0.53)	10.31 (0.73)
Morning/eveningness	53.82 (0.94)	56.50 (0.91)	58.23 (1.29)	60.77 (1.45)
Daily % sleep loss	0.46 (0.22)	0.79 (0.23)	1.14 (0.20)	1.14 (0.26)
B. Longhaul crews (n = 67)				
Extraversion	8.19 (0.70)	7.22 (1.81)	5.56 (1.00)	7.17 (1.02)
Neuroticism	11.96 (0.80)	13.00 (0.93)	11.56 (1.65)	10.21 (0.92)
Morning/eveningness	55.11 (1.52)	55.90 (2.81)	64.50 (2.18)	61.90 (1.77)
Daily % sleep loss	0.39 (0.29)	−0.48 (0.80)	1.23 (0.43)	1.38 (0.33)

C. One-way analysis of variance	F for all crews	F for longhaul crews
Extraversion	2.93*	0.98
Neuroticism	1.49	1.17
Morning/eveningness	5.74***	4.81**
Daily % sleep loss	2.05	3.36*

* $0.05 > p > 0.01$, ** $0.01 > p > 0.001$, *** $0.01 > p > 0.001$

0.05). There was a significant correlation between age and morningness ($F = 18.3$, $p < 0.01$), which accounted for 8% of the variance in morning/eveningness scores. Among longhaul flight crewmembers, subjects aged 50–60 reported significantly greater percentage sleep loss per day ($p < 0.05$) than subjects aged 30–40. Across all subjects, there was a significant positive correlation between age and the average daily percentage sleep loss (multiple $r^2 = 0.04$, $F = 8.50$, $p < 0.01$). The positive correlation was stronger for longhaul flight crewmembers (multiple $r^2 = 0.13$, $F = 9.86$, $p < 0.01$).

For the 91 flight crewmembers who provided at least one complete cycle of baseline temperature data, 1-way ANOVA (Table III) indicated that the temperature minimum occurred significantly later in subjects aged 20–30 than in those aged 30–40 ($p < 0.05$) or those aged 40–50 ($p < 0.05$). The local time of baseline sleep onset did not change significantly with age. The temperature minimum occurred significantly later ($p < 0.05$) in the baseline sleep episode (4.8 h after sleep onset) in subjects aged 20–30 than it did in subjects aged 30–40 (Table III).

The minimum of the daily temperature cycle increased significantly with age, being significantly greater ($p < 0.05$) in subjects ages 40–50 than in subjects aged 20–30. Since the daily maximum temperature did not change significantly with age, the amplitude of the baseline temperature cycle declined with age. It was significantly greater in subjects aged 20–30 than in subjects aged 40–50 ($p < 0.05$) and subjects aged 50–60 ($p < 0.05$), and significantly greater in subjects aged 30–40 than in subjects aged 40–50 ($p < 0.05$).

Factors Contributing to The Variance in Sleep-Loss

Multiple regression analyses (Table IV) indicated that among age, personality, and circadian variables, the most important predictors of sleep loss were the local time of the baseline temperature minimum and the amplitude of the baseline temperature rhythm. Greater average daily percentage sleep loss was associated with earlier baseline temperature minima and with lower amplitudes of the baseline temperature rhythm.

There was also a significant negative correlation ($F = 4.81$, $0.05 > p > 0.01$) between morning/eveningness scores and the local times of the temperature minimum; i.e., the more morning-type an individual was, the earlier his temperature minimum occurred. However this relationship accounted for only 5% of the variance in morning/eveningness scores.

DISCUSSION

Study Limitations

Before interpreting these findings further, it is necessary to identify a number of limitations which are inherent in the data. First, the data on sleep durations are subjective reports. In general, people are not able to estimate reliably the amount of sleep they obtain. However, a study comparing polygraphically-recorded sleep with subjective estimates of sleep duration in longhaul flight crews (12) found significant correlations between the two measures, suggesting that, at least in this subpopulation, subjective report has some systematic relationship to actual sleep duration. In the present analyses, atypical measures of baseline sleep duration would clearly contaminate calculations of sleep loss during trips, and the duration of baseline observations was limited (usually only 1–2 d). These analyses are also lim d in that they address only sleep duration, not sleep quality.

Second, the age-ranges of the flight crewmembers in the different types of flight operations were essentially non-overlapping (except among the military flight crews) and the military flight crews were significantly younger than the civilian flight crews. It was, therefore, impossible to compare simultaneously the effects of different flight operations and aging on average daily sleep loss. However, comparisons among the different types of military flight operations (longhaul, shorthaul, and combined longhaul/shorthaul) suggested that, at least among younger subjects, average daily sleep loss was largely independent of the type of operations flown. When data from the military and commercial longhaul crews were combined, the age-related increase in sleep loss was significant, with subjects aged 50–60 averaging 3.5 times more sleep loss per day than subjects aged 20–30.

Third, the baseline temperature rhythm data were collected while subjects continued their normal vi ties at home. In this totally uncontrolled setting, the circadian component of the temperature rhythm is over laid with shorter duration temperature fluctuations as sociated with changes in the level of physical activity The use of locally weighted regression smoothing an selection of the temperature minimum as the circadia phase marker were efforts to minimize contamination o the estimates of circadian parameters by activity mask ing effects.

TABLE III. COMPARISON OF CIRCADIAN PHASE AND AMPLITUDE (MEAN ± S.E.) ACROSS THE DECADES FROM 20 YEARS TO 60 YEARS OF AGE.

	A. All crews (n = 91) 20–30	30–40	40–50	50–60	B. One-way analysis of varian F for all crews
Local time of temp. min. (h)	4.74 (0.29)	2.78 (0.37)	3.08 (0.72)	4.68 (0.87)	6.06***
Local time of sleep onset (h)	23.91 (0.24)	23.64 (0.29)	23.72 (0.25)	23.85 (1.12)	0.29
Circ. phase of sleep onset† (h)	−4.84 (0.27)	−3.14 (0.37)	−3.36 (0.61)	−4.52 (1.23)	4.42**
Temperature minimum (°C)	36.04 (0.06)	36.21 (0.05)	36.39 (0.05)	36.20 (0.13)	5.05**
Temperature maximum (°C)	37.46 (0.06)	37.55 (0.05)	37.45 (0.07)	37.24 (0.20)	1.55
Amplitude of temp. rhythm (°C)	1.42 (0.05)	1.34 (0.06)	1.07 (0.06)	1.05 (0.13)	6.12***

[illegible] $p < 0.01$, **$0.01 > p > 0.001$, ***$0.001 > p > 0.0001$.

TABLE IV. MULTIPLE REGRESSIONS ANALYSES OF THE VARIABLES CONTRIBUTING TO SLEEP LOSS (n = 89).

All possible subsets regression	Stepwise regression
best subset: tt_{min}	$y = 2.30 - 0.17\ tt_{min} - 0.52\ t_{amp}$
multiple $r^2 = 0.069$	multiple $r^2 = 0.082$
$F = 6.44$, $0.05 > p > 0.01$	$F = 3.85$, $0.05 > p > 0.01$
$b^* = -0.166$, beta † $= -0.263$, $0.05 > p > 0.01$	

tt_{min}: local time of the baseline temperature minimum.
t_{amp}: amplitude of the baseline temperature rhythm.
* Unstandardized regression coefficient.
† Standardized regression coefficient.

Age-Related Changes

These analyses indicate a number of age-related changes which might be expected to influence the adaptation of flight crewmembers to duty demands. Older subjects were more morning-type than younger subjects, and age accounted for 8% of the variance in morning/eveningness scores. A number of studies have suggested that morning types have greater difficulty adapting to shift work and time zone changes (1,15,21,23,24,29). The physiological changes underlying the increasing morningness reported by older subjects remain to be elucidated. Theoretically, increasing morningness could be caused by shortening in the period of the circadian pacemaker with increasing age, and/or by altered sensitivity or exposure to social and sunlight zeitgebers. Of the two studies which have compared the period of the core temperature rhythm in young and old subjects in the absence of environmental time cues, one (32) reported significantly shorter periods in older subjects, while the other (33) found no significant differences. In the present study, the local time of the temperature minimum was correlated in the expected direction with the morning/eveningness score, however this relationship explained only 5% of the variance; i.e., less than age *per se*.

An age-related change in extraversion was found in the complete subject pool (n = 205) but not in the subset of longhaul flight crewmembers (n = 67). The only significant difference was that subjects aged 20–30 were more extraverted than subjects aged 30–40. Other studies have suggested that more extraverted subjects adapt more rapidly to schedule changes and time zone shifts (8,14,16). It seems plausible that extraverted subjects might enhance their exposure to social zeitgebers, by comparison with introverts. Thus, age-related changes in extraversion might lead to age-related changes in effective zeitgeber strength. However, the differences between the 20–30 age group and the 30–40 age group may also be an artifact of "cultural differences," since 88% of the 20–30 age group were military flight crewmembers, while 78% of the 30–40 age group were commercial flight crewmembers.

Among longhaul flight crewmembers, subjects aged 50–60 averaged significantly more sleep loss per trip day than subjects aged 30–40. The correlation between age and sleep loss explained 13% of the variance in average daily percentage sleep loss in this sub-population. A previous study, in which the sleep of commercial longhaul flight crews was recorded polygraphically, showed more disturbed sleep among older subjects before and after the first transmeridian flight of an international trip pattern (12). For the complete subject population (n = 205), ANOVA did not reveal any significant age-related changes in average daily percentage sleep loss. The correlation between age and sleep loss, while significant in this population, explained only 4% of the variance. It is possible that the differing demands imposed by the different types of flight operations may have confounded the age-related effects in the complete subject population. On the other hand, as noted previously, the average daily percentage sleep loss did not vary significantly among the different types of military flight operations. This suggests that, at least among younger flight crewmembers, differing operational demands may not be a major determinant of overall sleep loss during trips.

Significant age-related changes were found in several characteristics of the baseline temperature rhythm (data from 91 subjects from all types of flight operations). The local time of the temperature minimum was later in subjects aged 20–30 than in subjects aged 30–40 and 40–50. The daily minimum was lower in subjects aged 20–30 than in subjects aged 40–50. Consequently, the amplitude of the temperature rhythm declined with age, being greater in subjects aged 20–30 than in subjects aged 40–50 and 50–60, and greater in subjects aged 30–40 than in subjects aged 40–50. This decline in amplitude of the temperature rhythm confirms other work comparing disparate age groups (3).

Factors Contributing to The Variance in Sleep Loss

The multiple regression analyses reported here included data from subjects in all of the flight operations studied. They indicated that circadian parameters (local time of the minimum of the baseline temperature rhythm, and its amplitude) explained more of the variance in sleep loss during trips (7–8%) than age per se or personality measures. However, as noted above, it is possible that a relationship between age per se and sleep loss may have been obscured by the confounding effects of different types of flight operations. It was not possible to perform the multiple regression analyses on the subset of longhaul flight crewmembers, since only 31 of them provided adequate baseline temperature data. It is, thus, unclear whether age-related changes in the circadian system have a greater or lesser role than other (unidentified) age-related changes in the increasing average daily sleep loss on trips. It has been postulated (2) that the decline in amplitude of the circadian component

of sleep regulation is a causal factor in the less consolidated sleep and greater daytime sleepiness reported with aging.

It is interesting that the local time of the baseline temperature minimum was a significant predictor of daily percentage sleep loss while the morning/eveningness score was not. It is not clear why subjects with later temperature minima should experience less sleep loss on trips. However, this finding is consistent with the report (7) that subjects with late peaking temperature rhythms adjusted more rapidly to an 8-h eastward transmeridian flight than subjects with earlier peaking temperature rhythms.

Operational Considerations

As discussed previously, fatigue and sleep loss have been identified as important contributing factors in aviation incidents and accidents. There is a large literature demonstrating performance decrements with experimentally-induced sleep loss (reviewed in 13). We have recently demonstrated that giving commercial longhaul flight crewmembers a preplanned sleep opportunity during long overwater flights can improve reaction times and reduce EEG/EOG microevents during the critical approach and landing phases of flight (28).

In all of the different flight operations studied, there were some individuals who incurred major sleep loss. The average daily percentage sleep losses were not very great; however, this metric tends to underestimate the severity of the problem for three reasons. First, there were large individual differences in all age groups. Second, the average daily values do not convey the variability in sleep patterns across a trip; i.e., days when crewmembers experienced little or no sleep loss, and days when large sleep losses occurred. Third, they do not address the magnitude of the sleep loss accumulated over successive duty days. In the laboratory, sleep restriction of as little as 1 h per night causes a cumulative increase in physiological sleepiness during the day (5). Detailed analyses in each operating environment are being carried out to identify which types of schedules produce major sleep loss (e.g., 17,18).

The present analyses indicate that age-related changes occur in the circadian system which might be expected to reduce the amount of sleep obtained by flight crewmembers on trips (2). Daily percentage sleep loss was also found to increase significantly with age, particularly when subjects flying similar operations (longhaul) were considered. It should be noted that laboratory studies (32), indicate greater variability among older subjects in sleep and circadian rhythm parameters. This reflects the fact that all individuals do not age physiologically at the same rate, and supports the distinction (2) between physiological age and chronological age. Nevertheless, among crewmembers flying longhaul operations, subjects aged 50–60 averaged 3.5 times more sleep loss per day than subjects aged 20–30. This suggests that experience alone does not counteract the effects of physiological aging. Taken together, these findings indicate that countermeasures for circadian disruption and sleep loss in aviation may need to be adapted for different age groups and/or circadian types.

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