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How well do international aircrew sleep during layovers?

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ABSTRACT

Aims. Disruption to the internal body clock caused by rapid time zone changes may interfere with international aircrews' sleep during layovers. The extent of this disruption may depend on the direction of flight and the number of time zones crossed. The aim of the current study was to compare the length and quality of sleep episodes obtained by aircrew during layovers in Asia, Europe, and the US, with sleep obtained at home in Australia.

Method. A total of 71 international aircrew (66 male, 5 female) wore wrist activity monitors and kept sleep/wake and flight/duty diaries for at least 15 consecutive days while they worked their normal roster patterns. Data from the activity monitors and sleep/wake diaries were used to determine sleep length, sleep efficiency, sleep quality, and the restorative value of sleep.

Results. Factorial ANOVA indicated that region and time of sleep onset had significant main and interaction effects on all four dependent variables. In particular, sleep length was shorter, sleep efficiency was lower, self-rated sleep quality was lower, and the restorative value of sleep was lower during layovers in Asia, Europe, and the US, than at home in Australia.

Conclusions. The current data demonstrate the difficulty that aircrew face in obtaining sleep during layovers after transmeridian flight. If aircrew are unable to sufficiently recover during layovers, they may experience relatively high levels of work-related fatigue during homebound flight.

Keywords. sleep length, sleep quality, fatigue, time zones, aircrew.
BACKGROUND

Aircrew often experience relatively high levels of fatigue because they work irregular schedules that involve long work periods, early departures, late arrivals, night work, and rapid time zone transitions (Samel et al., 1995). This is an important safety issue given that aircrew fatigue has been identified as a contributing factor in several near-misses, incidents, and fatal accidents in civil aviation (Coleman, 1986; Caesar, 1986; Green, 1985; Cabon et al., 2000; Lyman & Orlady, 1980).

The sleep disruption associated with transmeridian flight (i.e. flight across several time zones) may be a major contributor to aircrew fatigue (Gander, et al., 1998a, 1998b). Sleep is disturbed by transmeridian flight because the sleep/wake cycle (and several other physiological variables) fluctuate rhythmically with a 24-hour period that is endogenously generated by the circadian timing system (Carskadon & Dement, 1975, 1977; Lavie, 1986; Lavie & Scherson, 1981; Lavie & Zomer, 1984). The most important zeitgebers (i.e. time givers) for the human circadian system are the light/dark cycle and social cues (Klein & Wegmann, 1980; Wever et al., 1983). Transmeridian flight causes a rapid phase shift in these zeitgebers to which the circadian system is unable to instantly re-entrain (Wever, 1980). The resultant desynchrony can lead to difficulty initiating or maintaining sleep, and may also cause daytime sleepiness, decreased alertness, and impaired performance (Klein & Wegmann, 1980; Loat & Rhodes, 1989; Manfredini et al., 1998; Wegmann & Klein, 1985; Winget et al., 1984; Wright et al., 1983).

The aim of the current study was to determine the impact of transmeridian flight on the quantity and quality of sleep that aircrew obtain by comparing their sleep at home (on the east coast of Australia) with their sleep during layovers in Asia, Europe, and the US. Previous studies have shown that the rate of resynchronisation of the circadian timing system with local zeitgebers depends on the number of time zones crossed and the direction of flight. Typically, resynchronisation is faster if more time zones are crossed and if flight is in a westward direction (Aschoff et al., 1975; Harma et al., 1994; Klein & Wegmann, 1980; Suvanto et al., 1990; Winget et al., 1975). Thus, it was hypothesised that (i) sleep episodes would be shorter and sleep quality would be lower during layovers than at home, and (ii) sleep episodes would be shorter and sleep quality would be lower during layovers after eastward flight than during layovers after westward flight.
METHODS

Participants
A total of 71 international aircrew (27 captains, 19 first officers, 25 second officers; 66 male, 5 female) participated in the study after responding to recruitment notices posted on notice boards and to the employer company’s intranet. All participants signed a consent form that signified their informed consent, confirmed their volunteer status, and stated that they understood their rights and obligations. All participants were assigned a unique identification code to ensure their anonymity. Participants did not receive any additional payment for participating in the study above their usual salary. The study was approved by the University of South Australia Human Research Ethics Committee using guidelines established by the National Health and Medical Research Council of Australia.

Procedure
Participants each wore wrist activity monitors and kept sleep/wake and flight/duty diaries for at least 15 consecutive days while they worked their normal roster patterns. In the sleep/wake diary, participants recorded sleep location, sleep start and end times, pre- and post-sleep fatigue levels, and self-rated sleep quality for all sleep periods (including naps). In the flight/duty diaries, participants recorded flight start and end times, flight origin and destination, and pre- and post-flight fatigue levels.

Measures and Data Analysis
Measures extracted from the activity monitor records and sleep/wake diaries included:
- Sleep Length: period between sleep onset time and wake up time, less awakenings.
- Sleep Efficiency: the percentage of time in bed that is actually spent sleeping.
- Sleep Quality: self-rating of sleep quality (reverse-scored on a scale of 1-5 such that higher scores indicate higher quality).
- Restorative Value of Sleep: difference between self-ratings of pre-sleep fatigue level and post-sleep fatigue level (higher positive scores indicate greater restorative value).

Separate two-way factorial analyses of variance (ANOVA) were conducted to determine the effects of region (home, Asia layover, Europe layover, US layover) and time of sleep onset (local time in 6-hour bins) on the various measures of sleep length and sleep quality. Post hoc analyses were conducted with Fisher’s PLSD where required.
RESULTS

Factorial ANOVA indicated that region ($F_{3,1952}=9.42$, $p<.0001$) and time of sleep onset ($F_{3,1952}=209.85$, $p<.0001$) had significant main effects, and a significant interaction effect ($F_{9,1952}=17.82$, $p<.0001$), on sleep length (Figure 1). Post hoc analyses revealed that sleep length was significantly shorter during layovers than at home: sleeps at home were 1.14 hours longer than sleeps during layovers in Asia ($p<.0001$), 2.22 hours longer than sleeps during layovers in Europe ($p<.0001$), and 0.95 hours longer than sleeps during layovers in the US ($p<.0001$). Post hoc analyses also revealed that sleep length was significantly shorter for sleeps that began during the daytime (i.e. 0600-1800h) than for sleeps that began during the night-time (i.e. 1800-0600h) (all $p<.0001$).

Factorial ANOVA indicated that region ($F_{3,1899}=7.84$, $p<.0001$) and time of sleep onset ($F_{3,1899}=20.28$, $p<.0001$) had significant main effects, and a significant interaction effect ($F_{9,1899}=4.15$, $p<.0001$), on sleep efficiency (Figure 2). Post hoc analyses revealed that sleep efficiency was significantly lower during layovers than at home: sleep efficiency at home was 3.03 percent greater than sleep efficiency during layovers in Asia ($p<.0001$) and 3.84 hours percent greater than sleep efficiency during layovers in Europe ($p<.0001$). Post hoc analyses also revealed that sleep efficiency was significantly lower for sleeps that began during the daytime than for sleeps that began during the night-time (all $p<.01$).

Factorial ANOVA indicated that region ($F_{3,1874}=3.96$, $p<.01$) and time of sleep onset ($F_{3,1874}=8.20$, $p<.0001$) had significant main effects, and a significant interaction effect ($F_{9,1874}=2.24$, $p<.05$), on sleep quality (Figure 3). Post hoc analyses revealed that sleep quality was significantly poorer during layovers in Asia and Europe than at home (both $p<.001$), and that sleep quality was significantly poorer for sleeps that began during the daytime than for sleeps that began during the night-time (all $p<.0001$).

Factorial ANOVA indicated that region ($F_{3,1952}=3.42$, $p<.05$) and time of sleep onset ($F_{3,1952}=9.50$, $p<.0001$) had significant main effects, and a significant interaction effect ($F_{9,1952}=2.44$, $p<.01$), on the restorative value of sleep (Figure 4). Post hoc analyses revealed that the restorative value of sleep was significantly lower during layovers in Asia, Europe, and the US than at home (all $p<.0001$), and that the restorative value of sleep was significantly lower for sleeps that began during the daytime than for sleeps that began during the night-time (all $p<.0001$).
Figure 1. Mean sleep length (± s.e.m.) as a function of time of sleep onset for sleeps (a) at home, (b) during layovers in Asia, (c) during layovers in Europe, and (d) during layovers in the US.
Figure 2. Mean sleep efficiency (± s.e.m.) as a function of time of sleep onset for sleeps (a) at home, (b) during layovers in Asia, (c) during layovers in Europe, and (d) during layovers in the US.
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**Figure 3.** Mean sleep quality (± s.e.m.) as a function of time of sleep onset for sleeps (a) at home, (b) during layovers in Asia, (c) during layovers in Europe, and (d) during layovers in the US.
Figure 4. Mean restorative value of sleep (± s.e.m.) as a function of time of sleep onset for sleeps (a) at home, (b) during layovers in Asia, (c) during layovers in Europe, and (d) during layovers in the US.
DISCUSSION

Before the results are discussed, it is important to note that (i) the current study represents a preliminary analysis of data collected in an on-going project, and (ii) one of the main dependent variables in the current study was the length of sleep episodes, rather than the total amount of sleep obtained per day. (For a detailed examination of the total amount of sleep obtained by aircrew at home and during layovers, refer to the paper by Darwent et al. in this issue.)

The first hypothesis, that sleep episodes would be shorter and sleep quality would be lower during layovers than at home, was supported. Specifically, sleep length was shorter, sleep efficiency was lower, self-rated sleep quality was lower, and restorative value of sleep was lower during layovers in Asia, Europe, and the US, than at home in Australia. This sleep disruption may have occurred because the circadian timing system is unable to immediately re-entrain to local zeitgebers after transmeridian flight (Wever, 1980). Consequently, international aircrew face a dilemma: if they attempt to sleep during local night, their sleep occurs out of phase with their internal body clocks, but if they attempt to sleep during local day, their sleep occurs out of phase with local time cues (i.e. environmental, social).

The second hypothesis, that sleep episodes would be shorter and sleep quality would be lower during layovers after eastward flight than during layovers after westward flight, was not supported. In fact, sleep episodes were longer and sleep efficiency was greater during layovers in the US (after eastward flight) than during layovers in Europe (after westward flight). This was unexpected given that eastward flight is usually considered more disruptive than westward flight (Aschoff et al., 1975; Harma et al., 1994; Klein & Wegmann, 1980; Suvanto et al., 1990; Winget et al., 1975). This curious finding may be explained by the fact that westward flight from Australia to Europe involved a greater time zone transition than eastward flight from Australia to the US.

The current data demonstrate the difficulty that aircrew face in obtaining sleep during layovers after transmeridian flight. If aircrew are unable to sufficiently recover during layovers, they may experience relatively high levels of work-related fatigue during homebound flight.
REFERENCES


