Variation in sleep duration and circadian phase by duty start time among short-haul commercial airline pilots

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Background

- Most studies examining circadian phase in commercial aviation have focused on alertness and performance during long-haul operations
- Short-haul operations involve high workload (route complexity, airspace and airport congestion) and intensive scheduling with multiple takeoffs and landings during a single duty day increasing the opportunity for operational performance errors (Bourgeois-Bougrine et al. 2003); CAA 2005-4)
- Chronic sleep restriction common among commercial airline pilots (Kecklund, et al. 1997; Gander et al. 2013; Bostock and Steptoe 2013)
- The magnitude and direction of phase shifts among short-haul pilots is unknown
- Approximately a five hour range in habitual circadian phase and phase angle between individuals (Wright, et al. 2005)
- Inter-individual differences in baseline phase and timing of light exposure influence phase shifts (Wright, et al. 2001)

Specific Aims

To test the hypothesis that short-haul airline pilots:

- have a starting range of circadian phases similar to that observed in laboratory studies
- experience shifts in circadian phase based on duty start time
- experience shorter sleep duration and increased sleep disruption during early and late starts

Methods

- Short-haul pilots recruited from a single commercial airline (n = 44)
- Continuous data collection for 34 days
- Schedule design included four schedule types:
  - Baseline = low workload "easy" schedule, variable start time
  - Early Starts = scheduled duty before 9:00 AM, with multiple segments
  - Midday Starts = scheduled duty after 9:00 AM, ending before 24:00, with multiple segments
  - Late Finishes = scheduled duty ends after 24:00

Methods

- All pilots scheduled to complete same sequence (e.g. Figure 1)
  - 5 duty days in a block, followed by 3 rest days
- Sleep assessed through
  - Actigraphy (analyzed using Actiware, Minimitter-Respironics, Bend OR)
  - Daily sleep logs
- Circadian assessment of 6-sulfatoxymelatonin (aMT6s) levels obtained over 24 hour sequential urine samples binned in 4 or 8-hourly blocks immediately following each schedule rotation (n = 13)
- Repeated measures ANOVA, and mixed-effects regression models comparing sleep duration, sleep latency, sleep efficiency and wake after sleep onset (WASO) by duty block
- aMT6s values in ng/mL were converted to ng/h and subjected to best fit cosine analysis (SAS software, version 9.2 Cary NC) to analyze the patterns of the 24-hour urine collection

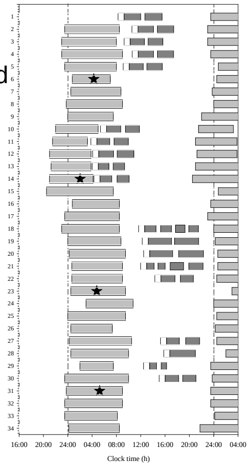

Figure 1. Representative plot of one study participant. Light gray bars represent sleep (double plotted), dark gray bars represent flight time, open bars indicated non-flight duty time, stars represent circadian acrophase.

Results

- Flight start times varied as expected (Table 1)

Table 1. Flight characteristics among all participants

	n (of duty days)	Flight 1 Start Time (SD)	Range (clock h)	Number of flight sectors (SD)	Flight duration (SD)
Baseline	167	10:17 (3:50)	04:43-19:25	2.01 (0.15)	2.36 (0.73)
Early starts	196	05:24 (0:38)	04:23-07:19	2.01 (0.07)	2.09 (0.52)
Mid starts	171	13:52 (1:20)	11:36-19:54	2.82 (0.98)	2.47 (1.12)
Late starts	176	16:33 (1:33)	11:09-22:57	2.01 (0.21)	2.83 (1.47)

Results

- Early and late starts associated with short sleep relative to baseline ($p < 0.05$) and sleep declined by day on early starts ($p < 0.05$; Figure 2)
- No differences in sleep latency, sleep efficiency or WASO by schedule type
- Baseline circadian phase ranged from 02:04-06:33
- The magnitude and direction of phase shifts differed between individuals even on the same schedule rotation (Figure 3)

Table 2. Participant Characteristics

N	44
Age	30.8 (± 7.1)
Height (cm)	179.6 (± 5.8)
Weight (kg)	78.0 (± 10.2)
BMI (kg/m^2)	24.15 (± 2.6)
Self-reported sleep need (h)	7.9 (± 0.7)
Commute time (m)	40 (± 22)
	n (%)
Female	4 (9)
Marital Status	
Single	30 (68)
Married	14 (32)
Current smokers	2 (5)
UK citizens	34 (77)
Shared housing	21 (49)

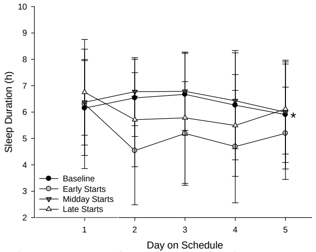

Figure 2. Mean sleep duration by day on each schedule. The analysis of response profiles declined significantly by day on shift on the early schedule compared to baseline ($p < 0.05$)

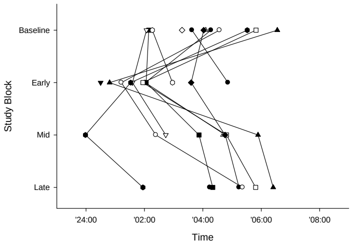

Figure 3. Cosinor-derived aMT6s acrophase by schedule for each of the 13 participants who completed the urine collection.

Conclusions

- Sleep duration is shorter on early and late starts schedule types relative to baseline
- Circadian phase among short-haul pilots with a nearly five-hour range following baseline duty schedules
- Inter-individual differences in the direction and magnitude of phase shifts are apparent in each duty type
- Predictive scheduling models that do not account for circadian phase should be used with extreme caution