CP 599

Early Starts: Effects on Sleep, Alertness, and Vigilance

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SUMMARY

Early starts and irregular work schedules might lead to disruption of sleep-wake rhythms with consequent sleep loss and fatigue. Fatigue is known to be a contributing factor to operational errors. The aim of this study was to determine the effects of early reporting times and irregular duty schedules on sleep, alertness and performance of pilots flying short-haul operations. *Method*: 6 Captains flying short-haul charters were measured during two 4-week periods. Subjects were equipped with a palmtop computer and an actigraph for subjective and objective measurement of sleep parameters, alertness, and performance on a vigilance dual-task. Each day subjects had to perform measurements before, during, and after flights and before and after the main sleep period. *Results*: It was found that pilots reporting before 06:00 a.m. had a significant shorter total sleep time, impaired sleep quality, and impaired performance both pre-flight and at top of descent. To a lesser degree, this also applied for reporting between 06:00 and 09:00 a.m. Degradation of sleep was most significant during the night prior to the start of a new duty period. *Conclusion*: Performance was primarily affected by inadequate sleep related to reporting times before 06:00 a.m. It is recommended that reporting times before 06:00 a.m. should be avoided, whenever possible. Pilots who have to report early, should try to anticipate insufficient sleep by advancing their sleep phase. This can only be achieved when early starts are planned on a regular basis. When irregular early starts are unavoidable, it should be considered to compensate for sleep reduction by planning sufficient time for recovery sleep.

1 INTRODUCTION

Due to increasing congestion of the European airspace and maximal utilization of aircraft, pilots of European short-haul charter operations are confronted with irregular shift work and early starts. Early morning starts require pilots to go to bed in the early evening, when their biological clock is not ready for sleep. This might lead to reduction of total sleep time and quality of sleep. Although pilots engaged in short-haul operations can be considered as shift workers, their schedules are often more irregular than those of shift workers in other industries. Irregularity may hinder habituation of the internal biological rhythm, and therefore problems in short-haul pilots might be more complicated than in regular shift workers. In regular shift work, it was evidenced that performance decrements were more frequent during the night shift, than during the morning shift (1).

In the case of short-haul pilots, sleep-wake rhythms will be disrupted with consequent sleep loss and fatigue. Fatigue and sleepiness are recognized as contributing factors to operational errors and aircraft accidents (2,3,4,5). Pre-dawn operations between 3:00 and 6:00 a.m. require pilots to perform in a period when their circadian rhythm dictates sleep and alertness is minimal (6). Sleep loss exacerbates this situation by increasing the level of sleepiness (7).

Few field studies have addressed the effects of irregular early starts in short-haul operations. Studies by Gander & Graeber (8), James, Green & Belyavin (9), Kecklund, Åkerstedt & Lowden (10) provided evidence for sleep restriction in aircrew of short-haul commercial operations. Experiments on the effects of sleep restriction on the quality of sleep have consistently shown reductions in stage 2 and REM sleep (11,12,13). However, the results of experiments on the effects of sleep restriction on performance and daytime sleepiness are less clear. Performance on prolonged vigilance tasks seems to be more adversely affected by sleep reduction than other types of performance (11,14,15). In the context of flight duty time limitations and rest requirements, knowledge of the relationships between sleep, alertness, and performance in short-haul operations is of great importance. Therefore, the present study was designed to assess the effects of early reporting times on sleep, alertness, and vigilance of pilots engaged in short-haul charter operations.

2 METHOD

As measurements of subjects during a single flight will not produce data that are representative for the average workload of short-haul pilots, it was decided to measure each subject continuously during two periods of four weeks (8 weeks total). The use of methods which necessitate the presence of one or more investigators in the cockpit was avoided, because this precludes a regular flight operation (7). Therefore, in this study only 'pilot-friendly', non-interfering, and cost-effective objective and subjective methods were used, which did not necessitate the presence of an investigator onboard the aircraft.

Subjects

Participants of the study included 6 experienced captains (5 male, 1 female) flying short-haul charters within their regular duty rosters. Mean age was 36.6 years (range 31-47), mean flying experience 10.2 years (5-24), and mean total flight hours was 8336 hrs (range 3900-14.500). All participants considered themselves as good sleepers while at home. Subjects lived within 1 hour travelling time to the home base crew centre.

Assessment methods

Subjective and objective measures were used to determine the effects of short-haul operations during two 4-week periods on quantity and quality of sleep, alertness and performance. An actigraph device was used to record objective data during sleep at home and during

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stopover nights. Subjective and performance data were collected using a Psion-3a palmtop computer (Fig. 1). Each pilot was equipped with a personal actigraph and Psion-3a and all tests were self-administered.

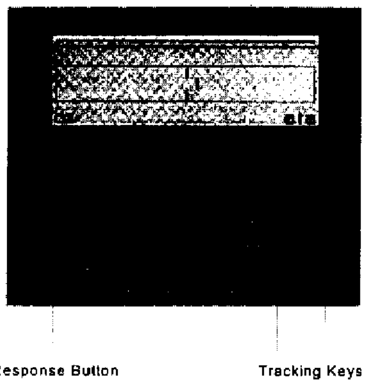

Fig. 1. Psion 3a: Vigilance and Tracking task (VigTrack)

The computer program (16) was menu driven and consisted of 4 main modules:

Sleep module
The sleep module consisted of a questionnaire including questions on sleep at home. Subjects had to record bedtime, latency, wake-up time, get up time, the subjectively estimated sleep length, and the use of sleeping aids. The quality of sleep at home and during stopovers was assessed by means of the Groningen Sleep Quality Scale (17). This scale has been used in a variety of studies on sleep disturbances among Dutch airline pilots (15, 18, 19). GSQS scores range from 0-14; higher scores indicate poorer sleep quality.

Alertness module
The Stanford Sleepiness Scale (20) was used to assess subjective alertness while at home/hotel or during flight operations. This subjective rating scale has proven to be sensitive in detecting any significant increase in sleepiness or fatigue. SSS measures showed to be highly correlated with flying performance and threshold of information processing speed during periods of intense fatigue (21). SSS scores range from 1-7. Higher scores indicate higher levels of sleepiness, equating lower levels of alertness.

Vigilance module
Fig. 1 shows the VigTrack task (16), which was used to measure vigilance performance while at home/hotel or during flights. This dual-task measures vigilance performance under the continuous load of a compensatory tracking task and was applied in studies on sedative effects of antihistamines, and alcohol (22, 23), and effects of cockpit naps (24). The duration of this test was 5 min. and performance measures included root mean square tracking error (RMS) and percentage omissions.

In-flight module
This module consisted of questions about napping strategies related to flight operation. Furthermore relevant flight data were stored.

Experimental design
During two 4-week periods, subjects were studied continuously under both rest and working conditions. Each day, subjects had to perform a test session after waking up and at bedtime. The wake-up test session consisted of the abovementioned sleep, alertness, and vigilance module. The bedtime test session included questions about napping, and the alertness and vigilance module. Wake-up and bedtime test sessions were classified into 4 different categories depending on duty status, 1) day off, 2) start duty period, 3) during duty period, and 4) end duty period. Furthermore a distinction was made between nights at home and during stopovers (hotel). During flight operation, subjects had to perform a test session just before top of descent. This in-flight test session consisted of the alertness, and vigilance module.

Statistical analyses
All variables were analysed using descriptive techniques. Those variables that were considered to be interesting for further analysis were tested using separate applications of a one-way analysis of variance (ANOVA). Post-hoc analyses (Duncan) were performed for comparison between the means of the different experimental conditions. Subjective ratings were analysed using non-parametric techniques (Wilcoxon Matched Pairs Signed-Ranks, Mann-Whitney U). Relationships between different variables and methods were investigated by using correlational computations (Pearson product-moment correlation coefficients or Spearman Rank correlational coefficients).

3 RESULTS

Sleep quantity and quality
Significant differences between the different duty status categories were found for bedtime ($F(3,254)=14.12$, $p<.001$), wake-up time ($F(3,254)=18.35$, $p<.001$), and total sleep time ($F(3,253)$, $p<.0001$). With respect to sleep, it was found that pilots slept 1-1½ hour shorter when on duty or starting a duty period, as compared to off-duty periods. It was demonstrated that pilots switching from a rest period (days off) to a duty period, experienced a significant shortage of total sleep time, increased sleep latency, and impaired sleep quality.

Alertness
Pilots were most alert at top of descent and most drowsy before going to bed. During and at the end of the duty periods pilots were significantly more drowsy at bedtime as compared to off-duty periods. Moreover, after waking up, pilots on duty felt more sleepy and less alert, as compared to waking up sessions during the off-duty periods ($F(2,752)=256.18$, $p<.001$).

Performance
Effects of fatigue on performance were most clearly demonstrated by the tracking component of the VigTrack task. Tracking performance was 10-15% better during the wake-up session, as compared to in-flight and bedtime values ($F(2,745)=8.32$, $p<.001$). Tracking per-

formance was worst at bedtime at the end of duty periods. Pilots tended to have a higher percentage of omitted targets on the vigilance component of this task after waking up as compared to bedtime values. This effect (5%) was primarily caused by the difference between wake-up and bedtime values at the start of, and during the duty period.

Duty schedules

During duty periods pilots had an average of 9 hours duty time and 6 hours flight time per day. Duty periods lasted 4 consecutive days on average. Pilots reported 1 hr prior to the scheduled start of the flights. It was found that reporting time was of major influence on total sleep time, sleep quality, alertness, and performance. The earlier pilots had to report, the shorter they slept, and the more sleep quality, alertness, and performance were impaired (Table 1).

Table 1: Correlation coefficients between reporting time, flight time, duty time, and total sleep time (TST), sleep quality (GSQS score), alertness (SSS score), and performance measures (VigTrack: tracking and % omissions).

	reporting time	flight time	duty time
TST	.441***		
GSQS	-.367***		
SSS	-.198*	-.009	.048
tracking	-.243**	-.034	.036
% omissions	-.228*	-.205*	-.173

*: p<.05; **: p<.01; ***: p<.001

Taking into consideration the frequency distribution of reporting times, data were analysed using 4 categories, depending on reporting time:

Group 1 (32 cases):	reporting before 06:00 hrs
Group 2 (24 cases):	between 06:00 and 09:00 hrs
Group 3 (21 cases):	between 09:00 and 15:00 hrs
Group 4 (35 cases):	after 15:00 hrs.

Effects of reporting time on sleep, alertness, and performance

Effects of reporting time on sleep are presented in Table 2. Significant differences between reporting time groups were found for bedtime ($F(3,111)=32.95$, $p<.0001$), sleep latency ($F(3,111)=5.63$, $p<.001$), total sleep time ($F(3,104)=18.25$, $p<.0001$), and sleep quality ($F(3,111)=7.68$, $p<.001$).

Pilots who had to report before 09:00 hrs (groups 1 and 2) went significantly earlier to bed as compared to those who had to report later (groups 3 and 4). Reporting before 06:00 hrs resulted in a significant longer sleep latency and significant shorter total sleep time as compared to later reporting times.
Furthermore, group 2 showed significantly shorter total sleep time as compared to groups 3 and 4. GSQS scores in groups 1 and 2 were significantly higher as compared to groups 3 and 4, indicating impaired sleep quality.

Pre-flight sleepiness was significantly higher in the group who had to report before 06:00 am (p<.05). As compared to the before 06:00 and 06:00-09:00 group, at top of descent levels of sleepiness were significantly higher in the group who reported after 15:00 (p<.05). This might be explained by the fact that most pilots in that group performed their top of descent tests in the late evening or during the night (late arrivals).

Effects of reporting time on vigilance performance during pre-flight and top of descent sessions, are presented in Fig. 2 (%omissions), and Fig. 3 (RMS tracking).

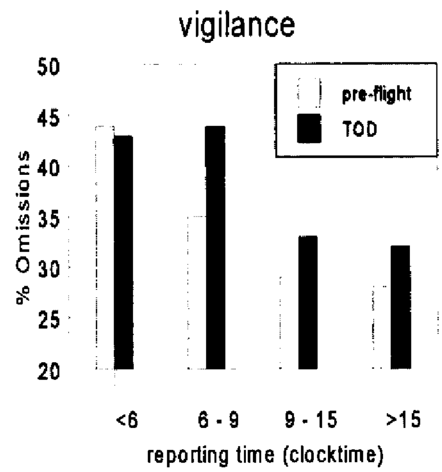

Fig. 2. Vigilance performance of the different reporting time groups: means of %omissions at 1 hr before reporting (pre-flight) and prior to top of descent (TOD).

Table 2: Bedtime, latency, total sleep time as measured by actigraphy, and sleep quality scores (GSQS) for the 4 different reporting time categories. Data are presented as means (±SD).

	Group 1 before 06:00	Group 2 06:00 - 09:00	Group 3 09:00 - 15:00	Group 4 after 15:00
Bedtime (local)	21:50 (00:55)	22:38 (01:12)	00:45 (01:50)	01:35 (02:21)
Latency	00:38 (00:33)	00:24 (00:22)	00:17 (00:17)	00:17 (00:17)
Total sleep time	05:09 (01:01)	05:52 (01:15)	07:06 (01:27)	07:11 (01:12)
Sleep quality score	6.1 (4.0)	5.0 (3.6)	2.2 (2.9)	2.7 (3.3)

As is shown in Fig. 2, reporting before 06:00 was associated with significant impaired vigilance performance (%omissions) pre-flight (p<.05) and at top of descent (p<.05). At top of descent, the same effect was found for the group that reported between 06:00 and 09:00 (p<.05).

In Fig. 3, it is shown that pre-flight and top of descent tracking performance (RMS) was significantly impaired in the group reporting before 06:00, as compared to the groups reporting between 09:00 and 15:00, and after 15:00 (pre-flight: p<.05, top of descent: p<.05).

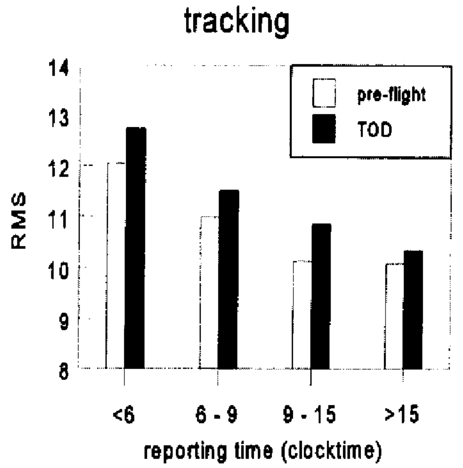

Fig. 3. Tracking performance of the different reporting time groups: means of RMS of tracking error at 1 hr before reporting (pre-flight) and prior to top of descent (TOD).

4 DISCUSSION AND CONCLUSIONS

It was found that reporting time was of major influence on total sleep time, sleep quality, alertness, and performance. The earlier pilots had to report, the shorter they slept, and the more sleep quality, daytime alertness, and performance were impaired. These effects were most significant when pilots had to report before six o'clock in the morning, but could also be demonstrated when they had to report between six and nine o'clock a.m. Reporting before 06:00 a.m. was associated with significant decreased total sleep time, sleep quality, decreased daytime alertness, and impaired performance. This impairment of performance was equally demonstrable during pre-flight and top of descent sessions. The degrading effects on pre-flight performance and performance at top of descent are of particular concern to flight safety. In this context, the results of the present study indicate that irregular early starts may have harmful effects on performance during critical phases of flight, such as take-off, approach, and landing.
The findings of the present study are in agreement with literature indicating that adverse effects of acute or chronic sleep reduction on subjective and performance measures might be expected when sleep is restricted to less than about 6 hours/day (11, 13).

In a healthy Dutch population, average sleep quality (GSQS) scores range between 1 and 3 (17). While literature generally emphasizes transmeridian operations as a major factor to cause sleep disturbances in aircrew (average sleep quality score: 5.4; (18)), the present study demonstrates that irregular early reporting times are at least as important in causing impaired sleep quality (average sleep quality score in the present study: 6.1).
Reduction of total sleep time and impairment of sleep quality were most significant during the night prior to the start of a new duty cycle. After an off-duty period, most pilots had to report early on the first duty day. They anticipated early rising by going to bed earlier than they were used to. This resulted in significantly longer sleep latencies, shorter total sleep times, and impaired sleep quality in the first night prior to a new duty period.

Although, daytime alertness was significantly affected by reduced sleep, most pilots appeared to compensate these negative effects, and showed to be able to maintain an adequate level of alertness during flight. However, frequent reduction of sleep might lead to a cumulative sleep debt, which pilots may no longer be able to compensate. This situation may lead to unacceptable levels of alertness and performance. Alertness and performance might be further degraded by pre-dawn reporting times between 03:00 and 06:00 a.m., which require pilots to perform in a period when their sleepiness is maximal. Sleep loss exacerbates this situation by increasing the overall level of sleepiness. Ideally, very early starts should be avoided. However, the present situation in the airline industry or demanding military missions will necessitate scheduling of early starts in a substantial number of cases. Pilots who have to report early, should try to anticipate insufficient sleep by advancing their sleep phase. This can only be achieved when early reporting times are planned on a regular basis. Thus, it is important to reduce irregularity whenever possible, in order to enable pilots to adapt to a regular work-rest pattern, which may consequently lead to prevention of sleep loss. In the case circumstances do not allow regular scheduling, it should be considered to compensate for sleep debt by planning sufficient time for recuperative sleep. In this context flight and duty time limitations and rest requirements should be evaluated. Implementation of new guidelines should include follow-up research to evaluate effects on sleep, performance, and alertness. The assessment methods applied in this study have proven their feasibility, practical relevance, and cost-effectiveness, and should be included in follow-up research.

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