Synopsis

Authorities around the world, as well as experts from NASA's Ames Research Center and the National Transportation Safety Board agree that pilot fatigue is an issue that must be addressed. This document presents findings from academic journals and research centres explaining the impact of fatigue on commercial aviators.

Contents

Aircrew Fatigue in Long-Haul Operations

Methods: Results

Additionally, the day-time flights were rated less stressful than the night flights. (Samel, Wegmann, & Vejvoda, 1997, p. 442)

When asked which factors (out of six) contributed most to the stress experienced during the different rotations, pilots ranked night flying to have the highest impact, on average. Duration of flight was ranked second, on average. (Samel, Wegmann, & Vejvoda, 1997, p. 442)

Because the layover period was only 14 hours, they went to bed upon arrival at the hotel (11:00LT) and slept during daytime. This sleep was 2 hours shorter, on average, than normal … and was disturbed by frequent awakenings. Five pilots (out of 22) slept for < 5 hours. (Samel, Wegmann, & Vejvoda, 1997, p. 444)

During the longer day-time flights between Germany and the U.S.-westcoast, an increasing level of fatigue with progressing flight duty was also observed. (Samel, Wegmann, & Vejvoda, 1997, p. 444)

Micro-sleeps multiplied after 8 hours of flight time during the day-time operations… and after 3 hours already during night-time operations. (Samel, Wegmann, & Vejvoda, 1997, p. 447)

During night duty, micro-sleeps were 1.2 per pilot per hour during the first 4 hours, and increased to more than 2.5 during the residual of the flight. A maximum was observed after 7 hours (with a rate of 4.5). (Samel, Wegmann, & Vejvoda, 1997, p. 447)

For the night flights on transmeridian routes, the number of critical fatigue scores was significantly correlated with the number of micro-sleeps. (Samel, Wegmann, & Vejvoda, 1997, p. 447)

Discussion: Sleep and rest

The average sleep loss of 8 hours as found in this study is in agreement with several studies performed in previous years (Buck et al., 1989; Graeber, 1986; Wegmann et all. 1986). The resulting sleep deficit occurring during night flight could only partly be compensated at the home base during the subsequent days. (Samel, Wegmann, & Vejvoda, 1997, p. 449)

In the north-south rotation, our sleep data indicate again that night flight is associated with a significant sleep deficit. (Samel, Wegmann, & Vejvoda, 1997, p. 449)

Based on the results from sleep, it must be concluded that at least 48 hours of rest (if not more to be on the safe side) are necessary for recovery from sleep deprivation after rotations as described in this report (Samel, Wegmann, & Vejvoda, 1997, p. 449)

Operational demands

Fatigue depends on several factors including time since sleep, circadian rhythms and time on task. (Samel, Wegmann, & Vejvoda, 1997, p. 450)

However, when FDP [flight duty period] was started in the late afternoon or at night, as was the case in the homegoing transmeridian flights… pilots were often awake for > 12 hours … or even 16 hours. (Samel, Wegmann, & Vejvoda, 1997, p. 450)

Consequently, fatigue began to increase soon after departure and fatigue was rated more frequently in the critical region. (Samel, Wegmann, & Vejvoda, 1997, p. 450)

In the DUS-ATL study, the number increased from one to two micro-sleeps per pilot per hour to about five after 5 hours of the night flight, and in the night flights from the U.S.-westcoast the number was between 3 and 4.5 after 6 hours flight time. (Samel, Wegmann, & Vejvoda, 1997, p. 450)

In the present studies, the mean flight duty time was 10 hours or more. Most fatigue ratings and the number of micro-sleeps showed an increasing trend with progressing flight duty. (Samel, Wegmann, & Vejvoda, 1997, p. 450)

Fatigue ratings and the number of micro-sleeps were significantly higher during night flights than during day-time flights, indicating a pronounced decrease of alertness and vigilance with progressing night duty. (Samel, Wegmann, & Vejvoda, 1997, p. 450)

However, the results from the majority of parameters investigated in this study leads to the conclusion that night duty imposes an extra burden on human physiology, and, therefore, time-on-task during night is particularly a crucial issue. (Samel, Wegmann, & Vejvoda, 1997, p. 450)

As a second conclusion, night duty is associated with lower alertness and vigilance than daytime duty. The mainly contributing factors are:

1. Night duty, since human functioning is depressed during the trough in circadian rhythmicity;
2. Sleep deprivation, because normal sleep is not possible during day-light hours; and
3. A long duty period which does not allow breaks for recuperation. (Samel, Wegmann, & Vejvoda, 1997, p. 451)

During night hours fatigue increases faster with ongoing duty. This leads to the conclusion that 10 hours of work should be the maximum for night flying. (Samel, Wegmann, & Vejvoda, 1997, p. 451)

Given what is known about the interference of long-haul operations with the circadian system and with the sleep-wake cycle, as well as the vigilance and alertness of the flight deck crew, it is somewhat surprising that only a few of the national rest-duty regulations presently in force sufficiently consider these aspects. (Samel, Wegmann, & Vejvoda, 1997, p. 451)

Based on the findings of present studies two-pilot crews should be limited to 12-hour FDPs during day-time operations and to 10-hour FDPs during night-time operations. (Samel, Wegmann, & Vejvoda, 1997, p. 451)

Principles and Guidelines for Duty and rest Scheduling in Commercial Aviation

General Principles

Each individual has a basic sleep requirement that provides for optimal levels of performance and physiological alertness during wakefulness. On average, this is 8 hours of sleep in a 24-hour period… (Dinges, Graeber, Rosekind, Samel, & Wegmann, May 1996, p. 2)

Required sleep and appropriate awake time off promote performance and alertness. These are especially critical when challenged with extended periods of wakefulness (i.e. duty), and circadian disruption (i.e., altered work/rest schedule). Recovery is important to reduce cumulative effects and to return an individual to usual levels of performance and alertness. (Dinges, Graeber, Rosekind, Samel, & Wegmann, May 1996, p. 3)

Flight Duty Periods

It is recommended that for standard operations, this cumulative flight duty period not exceed 10 hours within a 24-hour period. Standard operations include multiple flight segments and day or night flying. (Dinges, Graeber, Rosekind, Samel, & Wegmann, May 1996, p. 6)

Guidelines and recommendations

Flight duty period: 10 hrs. (Dinges, Graeber, Rosekind, Samel, & Wegmann, May 1996, p. 9)

Other Industry Strategies

[controlled rest] is absolutely not intended as a substitute for additional flight crew, appropriate rest facilities, or as support for extended duty. All possible strategies that maintain or improve the safety margin should be considered. (Dinges, Graeber, Rosekind, Samel, & Wegmann, May 1996, p. 10)

Crew Factors in Flight Operations IX: Effects of Planned Cockpit Rest on Crew Performance and Alertness in Long-Haul Operations

Operational Summary

"One natural compensatory response to the sleepiness and fatigue experienced in long-haul operations is unplanned, spontaneous napping and non-sanctioned rest periods." (Rosekind, et al., 1994, p. 2)

"An interesting finding emerged from analysis of the physiological data collected during the [No-Rest Group] 40 min. control period. Although instructed to continue usual flight activities, for [No-Rest Group] pilots fell asleep (a total of five episodes) for periods lasting from several minutes to over 10 min." (Rosekind, et al., 1994, p. 3)

Vigilance decrement functions also revealed that on night flights the [No-Rest Group] pilots had a level of performance that was significantly decreased relative to[Rest Group]pilots. (Rosekind, et al., 1994, p. 3)

During the last 90 min. of flight, each event greater than 5-sec. was scored for both the [No-Rest Group] and RG. There was at least one such microevent identified in 78% of the [No-Rest Group] and 50% of the RG. Overall, there were a total of 120 microevents that occurred in the [No-Rest Group] (with fewer subjects)… (Rosekind, et al., 1994, p. 3)

Overall, the analysis of subjective alertness ratings demonstrated that pilots reported lower alertness on night flights than on day flights and after the rest/control period than before it. (Rosekind, et al., 1994, p. 3)

The speed of falling asleep in the RG (5.6 min) is comparable to that seen in moderately sleep deprived individuals… also there were five episodes of sleep that occurred during the control period in four [NO-REST GROUP] pilots who had been instructed to continue usual flight operations. This result reinforces previous findings that pilots are poor evaluators of their level of physiological sleepiness. (Rosekind, et al., 1994, p. 4)

Conceptually and operationally, methods to minimize or mitigate the effects of sleep loss, circadian disruption, and fatigue in flight operations, can be divided into (1) preventative strategies and (2) operational countermeasures. (Rosekind, et al., 1994, p. 4)

Background

Pilot fatigue in long-haul flight operations is a major safety concern. Several sources lend support to this concern. Long-haul wide-body flight operations have almost a three-times higher loss ratio than combined short- and medium-range flights. (Rosekind, et al., 1994, p. 5)

… cockpit crew error, where pilot fatigue may be a contributing factor, has been related to 75% of aircraft losses since 1959. (Rosekind, et al., 1994, p. 5)

Measures: Physiological Alertness/Sleepiness

The term microsleep is often used to describe the brief occurrence of EEG theta activity that can be associated with a performance lapse. (Rosekind, et al., 1994, p. 13)

Therefore, this intensive analysis identified the occurrence of EEG and EOG microevents lasting 5 sec. or longer, associated with increased physiological sleepiness during the last 90 min. of flight for both the [No-Rest Group] and RG. (Rosekind, et al., 1994, p. 13)

Therefore, not only is the occurrence of sleep during the rest period important, but the speed at which crewmemembers fall asleep can be used as an indication of their level of physiological sleepiness. (Rosekind, et al., 1994, p. 13)

Measures: Performance: Sustained Attention/Reaction Time

Over the past 10 years, Dinges focused on the precise nature of performance impairment engendered by sleep loss and shifts in work-rest schedules. (Rosekind, et al., 1994, p. 15)

Results: Subject Characteristics

The [No-Rest Group] consisted of three crews totaling nine subjects. The [Rest Group] consisted of four crews totaling 12 subjects. (Rosekind, et al., 1994, p. 19)

Rest Period Sleep: NRG Subjects with Sleep During the Control Period

… that four [No-Rest Group] subjects fell asleep on a total of five occasions (one subject fell asleep during two different control periods). Four of the nine [No-Rest Group] subjects (44%) had at least one episode of spontaneous sleep during the control period …. Two of the periods were over 10min. long. (Rosekind, et al., 1994, p. 29)

Raw Data: Descriptive Analysis

The cumulative total microevents that occurred for all twenty-one crewmembers was 154. The nine [No-Rest Group] crewmembers had a total of 120 microevents (78%)… As expected, most of these microevents, 132 (86%), occurred in the hour before TOD [top of descent]. In the [No-Rest Group], 98 microevents occurred before TOD, with 22 microevents in the period from TOD through landing. (Rosekind, et al., 1994, p. 38)

Seven of nine [No-Rest Group] crewmembers had at least one microevent. Four of these seven (two captains and to FOs) had 9 or more total microevents that together accounted for 84% of the total [No-Rest Group] microevents. (Rosekind, et al., 1994, p. 38)

Overall, there were four [No-Rest Group] crewmembers who had more than 11 microevents; an [No-Rest Group] captain had the most occurrences, 42. At the other end of the range, only two [No-Rest Group] crewmembers had as few as 6 microevents. (Rosekind, et al., 1994, p. 38)

Raw Data: Statistical Analysis of Microevent Occurrences

Overall, the [No-Rest Group] crewmembers averaged significantly more cumulative total microevents, 6.37 [than] the [Rest Group] crewmembers, whose average was 2.90. (Rosekind, et al., 1994, p. 40)

Sleep Latency Results

The laboratory standard for a level of excessive physiological sleepiness is a sleep latency of 5 min. or less, sometimes referred to as the “twilight zone”. In this study, the [Rest Group] average was 5.6 min. to fall asleep. (Rosekind, et al., 1994, p. 41)

EEG Sleep Results

An interesting finding emerged from analysis of the physiological data obtained during the [No-Rest Group]’s control periods. Four of nine [No-Rest Group] subjects (44%) had at least one spontaneous episode of sleep during their 40-minute control period. The five sleep episodes lasted from a couple of minutes to over 12 min. To our knowledge, this is the first physiological documentation of an unplanned and involuntary sleep episode during long-haul flight operations. (Rosekind, et al., 1994, p. 51)

Physiological Alertness/Sleepiness Findings

For the descriptive analysis of the raw data, the cumulative total number of events for the fewer subjects and fewer opportunities in the [No-Rest Group] was 120 whereas there were 34 events in the RG. For the [No-Rest Group], 98 total microevents occurred before TOD with 22 events from TOD through descent and landing… (Rosekind, et al., 1994, p. 52)

Layover and Cumulative Sleep Loss WAM Findings

Eighteen of the 21 crewmembers (86%) developed a cumulative sleep debt of at least 4 hr. by the ninth day of the duty cycle. The worst accumulation represented 22 hr. of sleep loss by the ninth day. The overall average accumulated sleep loss was about 9 hr. (Rosekind, et al., 1994, p. 53)

Scientific and Operational Issues

Is a rest period the same as a sleep period? *NO.* It has been shown clearly that rest is not the same as sleep (Rosekind, et al., 1994, p. 59)

Fatigue in Transportation: NTSB investigations and safety recommendations

"… 20% of recent NTSB investigations have identified fatigue as a probable cause, contributing factor or finding." (Marcus & Rosekind, 2016, p. 1)

"Fatigue was also identified in … 23% of its major aviation investigations." (Marcus & Rosekind, 2016, p. 2)

28 of 51 total fatigue recommendations made by the NTSB were for scheduling policies and practices. (Marcus & Rosekind, 2016, p. 3)

"[this research] clearly demonstrates that fatigue remains a significant transportation safety risk, deserving of ongoing investigation and recommendations to reduce the safety events fatalities, injuries and environmental hazards associated with fatigue." (Marcus & Rosekind, 2016, p. 6)

References

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