AMBIENT LIGHT INTENSITY, ACTIGRAPHY, SLEEP AND RESPIRATION, CIRCADIAN TEMPERATURE AND MELATONIN RHYTHMS AND DAYTIME PERFORMANCE OF CREW MEMBERS DURING SPACE FLIGHT ON STS-90 AND STS-95 MISSIONS

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INTRODUCTION

Sleep disruption and associated waking sleepiness and fatigue are common during space flight. A survey of 58 crew members from nine space shuttle missions revealed that most suffered from sleep disruption, and reportedly slept an average of only 6.1 hours per day of flight as compared to an average of 7.9 hours per day on the ground. Nineteen percent of crewmembers on single shift missions and 50 percent of the crewmembers in dual shift operations reported sleeping pill usage (benzodiazepines) during their missions. Benzodiazepines are effective as hypnotics, however, not without adverse side effects including carryover sedation and performance impairment, anterograde amnesia, and alterations in sleep EEG.

Our preliminary ground-based data suggest that pre-sleep administration of 0.3 mg of the pineal hormone melatonin may have the acute hypnotic properties needed for treating the sleep disruption of space flight without producing the adverse side effects associated with benzodiazepines. We hypothesize that pre-sleep administration of melatonin will result in decreased sleep latency, reduced nocturnal sleep disruption, improved sleep efficiency, and enhanced next-day alertness and cognitive performance both in ground-based simulations and during the space shuttle missions.

Specifically, we have carried out experiments in which:

(1) ambient light intensity aboard the space shuttle is assessed during flight;
(2) the impact of space flight on sleep (assessed polysomnographically and actigraphically), respiration during sleep, circadian temperature and melatonin rhythms, waking neurobehavioral alertness and performance is assessed in crew members of the Neurolab and STS-95 missions;
(3) the effectiveness of melatonin as a hypnotic is assessed independently of its effects on the phase of the endogenous circadian pacemaker in ground-based studies, using a powerful experimental model of the dyssomnia of space flight;
(4) the effectiveness of melatonin as a hypnotic is assessed during the STS-90 (Neurolab) and STS-95 missions in a double-blind placebo-controlled trial. In both flight-based experiments, the effects of melatonin on sleep stages and spectral composition of the EEG during sleep will be determined as well as its effects on daytime alertness and performance;
(5) the impact of space flight on sleep and waking neurobehavioral alertness and performance in 30-45-year-old astronauts is compared with its impact in a 77-year-old astronaut. This case study is the first to assess the effects of space flight on an older individual.

Because the investigators are still blind to the treatment in this double-blind, placebo-controlled trial, preliminary results will be presented independent of the drug condition.

RESULTS

LIGHT LEVELS ABOARD THE SPACE SHUTTLE:

We recorded light levels in the mid-deck, the flight deck as well as in the Spacelab (STS-90) or Spacehab (STS-95). Actillumes were placed in these three compartments on FD-1 until the end of the mission. Preliminary results are presented for the Neurolab mission. On the flight deck, the recorded ambient light levels reflect the 90 minute orbital cycle (day and night) as well as the slightly shorter than 24 h rest-activity cycle. During the rest phase, even though the window shades on the flight deck were shut, the recurring orbital dawn can be observed in the recordings, with light levels reaching 10 lux. During the activity phase of the near 24-h days, ambient light varied with the orbital day and night such that during the orbital day light levels reached 10,000 lux. Very high light levels were sometimes observed during the late evening, just before the scheduled time of lights out. During the scheduled activity part of the day, the light levels recorded on the mid-deck were relatively constant (1-10 lux) and lower than in the Spacelab. In the Spacelab, light levels were constant and low (approximately 10-100 lux) during the working day. The approximately 20 min advance per day of the rest-activity cycle is visible in the recordings of light levels in the mid-deck. These data demonstrate that light levels vary between the different compartments of the spacecraft, are low in those compartments in which most of the crew spends most of the working day, and are variable and high on the flight deck. This variability indicates that light exposure (intensity and temporal distribution) depends strongly on the location within the spacecraft. However, no data on light exposure of individual astronauts are available. Therefore no prediction on the impact of these light levels on synchronization of the circadian system to the 23 h 40 min rest-activity cycle can be made. However, if some crew members were exposed to the high light levels present on the flight deck, especially during their time off in the evening, this evening light exposure in combination with the low levels during the day in the Spacelab would be expected to compromise circadian synchronization in those individuals. Routine recording light exposure in the spacecraft compartment together with ambulatory recording of light exposure of individual astronauts would provide the necessary information.

ACTIGRAPHY:

Actigraphic assessments of rest-activity cycles were successfully obtained in 4 crew members during the L-90, L-60, L-30 and L-7 pre-flight baseline data collection segments, during the in-flight segment, and during the post-flight segment of the Neurolab mission. The activity data reflect the approximately 20 minute advance of wake time during the 17 day mission as well as deviations from this schedule on 04/25/98 and 04/28/98. The data also illustrate that, on average, bedtimes advanced in the course of flight. Interestingly, the night to night variability in bedtimes appeared much greater than the variability in wake times. The data demonstrate that actigraphic assessments reliably represent the timing of the non-24-h rest-activity cycle that is dictated by operational constraints, and adherence to as well as deviations from this schedule. Preliminary assessment of total sleep time on the basis of these actigraphic recordings indicate that the four crew members slept on average 6.6 hours per day on this mission.

NEUROBEHAVIORAL PERFORMANCE:

We successfully obtained 62 neurobehavioral performance assessments (each approximately 25 minutes in duration) in four crew members during the pre-flight, in-flight and post-flight segments of the Neurolab mission. An additional 30 assessments were made in two crew members during the STS-95 mission. These data are currently being analyzed.

CORE BODY TEMPERATURE RECORDING:
Core body temperature was recorded with the Body Core Temperature Monitoring System (BCTM-3, PED, Inc., Wellesley, MA) in four STS-90 crew members and in two STS-95 crew members during the pre-flight, in-flight and post-flight segments of the mission. A total of 32 BCTMS sessions of approximately 32 hours each were acquired during the Neurolab and STS-95 missions. These data are currently being analyzed.

SLEEP LOGS:
Sleep logs were successfully obtained in 6 crew members during the L-90, L-60, L-30 and L-7 pre-flight baseline data collection segments as well as during the flight and post-flight segments of the Neurolab mission. These data are currently being analyzed.

POLYSOMNOGRAPHIC RECORDING OF SLEEP:
We obtained 64 recordings of the daily sleep episode in four Neurolab crew members during the pre-flight, in-flight and post-flight segments of the Neurolab mission and 30 nocturnal sleep opportunities in the two STS-95 crew members. Variables included EEG, EOG, and EMG. These signals were recorded on the digital sleep recorder (DSR, Temec Instruments, The Netherlands) and flash RAM cards. Application of bio-sensors to the skull and skin was achieved by an E-net (Physiometrix, Billerica, MA). The quality of physiological signals was monitored and evaluated by an artificial intelligence system called "PI-in-a-Box". It alerted the flight crew to possible anomalies and suggested procedures for correcting the problems. All sleep recordings were scored according to standard criteria by a registered polysomnographic technologist. For the Neurolab mission, total sleep time (TST) averaged 445 (SEM 7), 452 (SEM 5) and 446 (SEM 8) minutes during the L-60, L-30 and L-7 segments respectively. During flight, TST was reduced to 423 (SEM 16) minutes per flight day, whereas during the post-flight segment total sleep time increased to 459 (SEM 11) minutes. These changes in TST were accompanied by changes in sleep efficiency (SE) (SE= TST divided by the duration of the interval time between lights out and lights on) such that lowest sleep efficiencies were observed during the in-flight segment and highest sleep efficiencies were observed during the post-flight segment. The data indicate that total sleep time during the mission is reduced compared to the pre-flight segments and that after the flight this sleep loss is recovered by increased TST as well as increased sleep efficiency. The apparent discrepancies between TST as assessed by actigraphy and polysomnography may be explained by the observation that on nights during which crew-members recorded sleep polysomnographically, they selected to go to sleep at the scheduled clock time, whereas on the nights during which sleep was not recorded polysomnographically, sleep was often postponed.

PRELIMINARY CONCLUSIONS

While aboard the shuttle, astronauts live in an environment characterized by highly variable ambient light intensities. The associated pattern of retinal light exposure may jeopardize entrainment of the circadian timing system to the imposed rest-activity cycle that is required by operational constraints, which typically requires a rest-activity schedule that is, on average, shorter than 24 h. Total sleep time is reduced and sleep is disrupted in space. Whether or not this disruption can be successfully treated by melatonin administration will be assessed after the data are unblinded and analyzed by drug condition.