

Relation of age to circadian adjustment to night work

by Mikko I Härmä, MD,¹ Tarja Hakola, MSc,¹ Jarmo Laitinen, PhD²

Most shiftworkers have severe disturbances of their sleep and wakefulness at least occasionally (eg, insomnia, fatigue, and increased sleepiness). The disturbances occur mainly in connection with early morning and night shifts, circadian rhythmicity being the essential mechanism inducing them.

Aging has been found to increase the disturbances of sleep and wakefulness, the critical age being, on the average 40-50 years (1). The information is, however, based mainly on questionnaires, and it is not clear which physiological changes, if any, explain the adverse health effects of older shiftworkers.

According to earlier field studies, mainly on nurses, there are indications of slower circadian adjustment to nightwork among middle-aged shiftworkers than among younger ones (2, 3). The limited experimental data on physiological sleep tendency and performance also suggest that middle-aged subjects (>40 years) would tolerate experimental shift work worse than younger subjects (4, 5).

The objective of the present study was to determine the relation between age and the circadian adjustment to nightwork. The study was designed to provide data on the adjustment process across several consecutive days under closely controlled laboratory conditions.

Subjects and methods

Three groups of voluntary letter sorters were studied in a shift work laboratory. The mean age of the subjects was 23 (range 19-28, N=7), 39 (range 30-44, N=6) and 57 (range 53-59, N=7) years. All of the subjects were experienced shiftworkers, but older subjects had longer shift work experience. Both men (N=9) and women (N=11) were included in the study.

All of the subjects spent five days and nights in the shift work laboratory, which has noise-restricted sleep chambers and separate rooms for work and leisure time. After a habituation night, the subjects worked one morning shift and three consecutive night shifts in the laboratory. The morning shift lasted from 0900 to 1600 and the night shift from 2300 to 0600. The subjects were allowed to sleep after the morning shift

from 2230 to 0630, and after the night shift from 0630 to 1430.

Controlled letter sorting was carried out in the laboratory in a manner similar to that used in the actual workplace. During the experimental week, the subjects were not allowed to nap, jog, or take alcohol. Meal times were regular, and leisure time was spent watching television, reading, doing needlework, and the like.

Circadian rhythms. Rectal temperature was measured continuously every 3 min with a thermistor probe (YSI 401, Yellow Springs Instruments, United States). The mean temperatures for every 30 min were first calculated to smooth the variation. The occurrence of the minimum rectal temperature every 24 h was estimated from the smoothed data. Salivary melatonin and subjective sleepiness (Stanford sleepiness scale) were assessed every hour during the night shifts. For the melatonin analyses, unstimulated saliva (2.5 ml) was collected into polyethylene tubes and stored in a freezer (-20°C). Salivary melatonin was determined later by direct radioimmunoassay using a modification of Miles et al (6).

Sleep length and quality were registered by the static charge-sensitive-bed (SCSB) method (7). Using the SCSB method, we classified sleep as active, intermediate, or quiet in 3 min epochs, according to the corresponding changes in the measured ballistocardiogram, respiration frequency, and greater body movements. Quiet sleep corresponded mainly to the delta activity of the electroencephalogram (8).

Statistical methods. To estimate the amount of circadian adjustment, we first calculated the differences between the first and the third night shift days for most of the variables. For sleep length, the difference between the sleep after the morning shift and the three night shifts (mean) was used as the test variable. One-way analyses of variance with Duncan's posthoc tests were calculated to test the differences in circadian adjustment between the age groups.

Results

From the morning to the third night shift day, the minimum of the rectal temperature was delayed 5.9, 3.3, and 2.3 h (mean) in the young, middle-aged, and old

¹ Institute of Occupational Health, Department of Physiology, Helsinki, Finland.

² University of Kuopio, Kuopio, Finland.

Correspondence to: Dr Mikko Härmä, Institute of Occupational Health, Department of Physiology, Laajaniityntie 1, SF-01620 Vantaa, Finland.

groups, respectively. The difference between the groups was significant ($P < 0.05$). From the first to the third night shift, the rectal temperature minimums were delayed less (figure 1a), but, in the youngest age group, the delay was significantly greater than in the older one ($P > 0.05$).

Salivary melatonin had an increased trend during the night shifts, the highest values being obtained mostly at 0600. The sharp increase in the salivary melatonin level during the night shift stayed similar during the consecutive night shifts in the old and middle-aged groups but became more sloped in the youngest age group. Consequently, the mean salivary melatonin decreased in the youngest age group during the third night shift (figure 1b).

From the morning shift to the night shifts (mean of the three day sleeps), sleep length (time in bed) decreased 1.5 h and 1.2 h in the middle-aged and oldest groups, but increased 0.4 h in the youngest group. The

decrease in the amount of quiet sleep differed significantly ($P > 0.01$) between the age groups (figure 1c).

From the first to the third night shift, subjective sleepiness (mean) changed differently between the age groups ($P > 0.001$) (figure 1d). Sleepiness during the consecutive night shifts decreased in the youngest but did not change in the oldest age group (difference $P < 0.05$).

Discussion

The results indicate that aging decreases circadian adjustment to nightwork, the change becoming obvious already before retirement age. The results were homogeneous concerning both the results of endogenous circadian rhythms (temperature and melatonin) and the circadian rhythm of sleep and wakefulness.

The length and structure of sleep is known to depend on the endogenous circadian phase (9, 10). It would be tempting to speculate that the observed de-

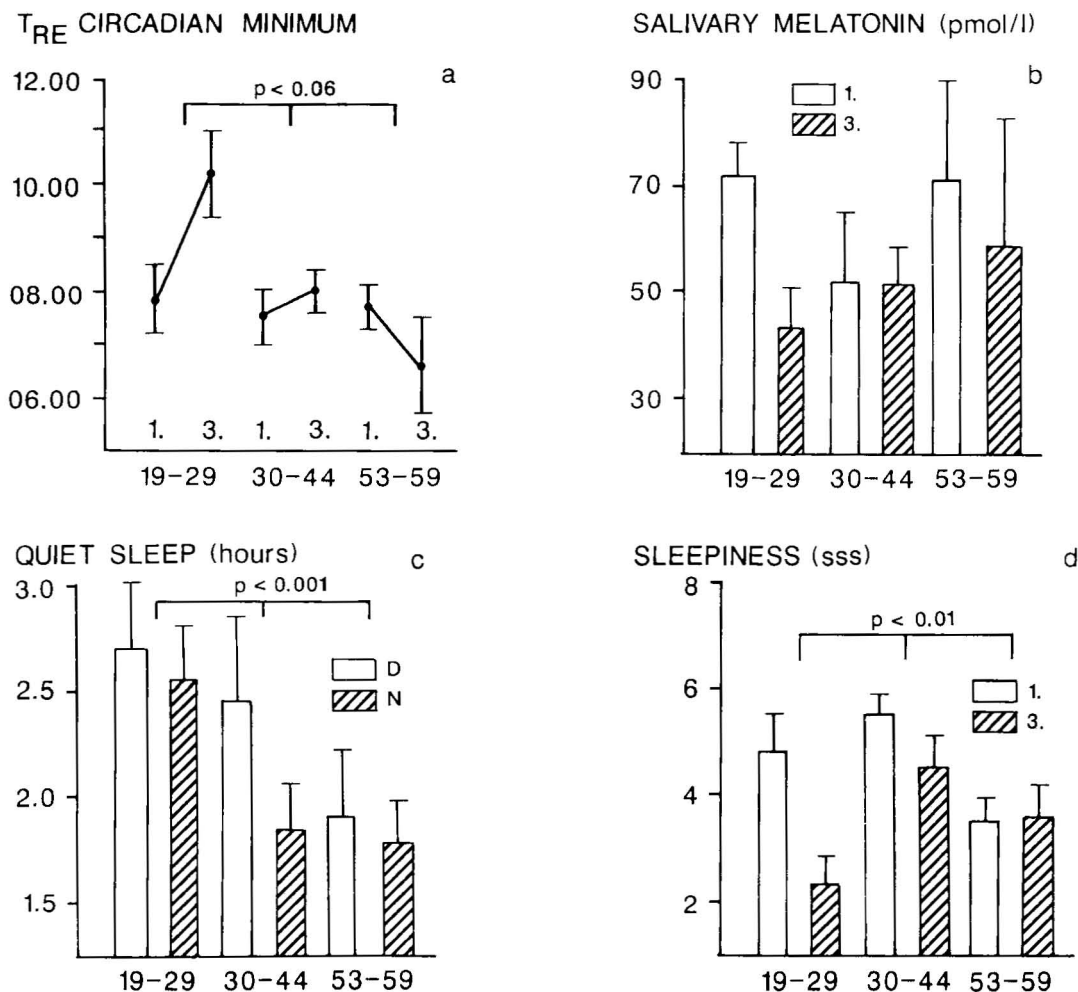


Figure 1. Changes in (a) rectal temperature (T_{RE}) circadian minimum, (b) mean salivary melatonin, (c) amount of quiet sleep according to the static charge-sensitive-bed method after the day (D) and the three night shifts (N, mean), and (d) mean ratings of sleepiness during the first (1.) and third (3.) night shifts in different age groups. Statistical differences (ANOVA) of the change between the shifts shown in the figure. (19-29, 30-44, 53-59 = age groups in years)

crease in sleep length and the older shiftworkers' inability to increase their alertness during the consecutive night shifts would have been caused by their basic inability to adjust their endogenous circadian rhythmicity to night work. The fast circadian adjustment of the youngest group would, on the other hand, explain why they could sleep so well after the night shifts and why they could even increase their alertness during the consecutive night shifts.

It is also notable that aging was associated with a decrease in quiet or "deep" sleep, which corresponds mainly with the slow-wave sleep in the electroencephalogram (8). Since slow-wave sleep is crucial for the brain to recover from sleep deprivation, the decrease in the slow wave sleep after the night shifts might be an important mechanism through which aging decreases shift work tolerance.

References

1. Koller M. Health risks related to shift work. *Int Arch Occup Environ Health* 1983;53:59—75.
2. Matsumoto K, Morita Y. Effects of night-time nap and age on sleep patterns of shiftworkers. *Sleep* 1987;10:580—9.
3. Härmä MI, Knauth P, Ilmarinen J, Ollila, H. The relation of age to the adjustment of the circadian rhythms of oral temperature and sleepiness to shift work. *Chronobiol Int* 1990;7:227—33.
4. Walsh JK, Sugerman JL, Muehlbach MJ, Schweitzer PK. Physiological sleep tendency during sleep-wake schedule inversion in young and middle-age adults. *Sleep Res* 1987;16:653.
5. Webb W. Experiments on extended performance: repetition, age, and limited sleep periods. *Behav Res Methods Instrum Comput* 1985;17:27—36.
6. Miles A, Philbrick D, Tidmarch SF, Shaw DM. Direct radioimmunoassay of melatonin in saliva. *Clin Chem* 1985;3:1412—3.
7. Alihanka J. Sleep movements and associated autonomic nervous activities in young male adults [dissertation]. *Acta Physiol Scand Suppl* 1982;511.
8. Hasan J, Alihanka J. Construction of REM-NREM sleep hypnograms on body movements recordings. In: Koella WP, ed. *Sleep* 1980. Basel: Karger, 1981:344—47.
9. Czeisler C, Weitzman E, Moore-Ede M, Zimmerman J, Knauer R. Human sleep: its duration and organization depend on its circadian phase. *Science* 1980;210:1264—7.
10. Czeisler C, Zimmerman J, Ronda J, Moore-Ede M, Weitzman E. Timing of REM sleep is coupled to the circadian rhythm of body temperature in man. *Sleep* 1980;2:329—46.