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All-Night Sleep Polygraphic Recordings of Healthy Aged Persons: REM and Slow-Wave Sleep

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Summary: All-night polygraphic recordings of 15 healthy aged persons (82.1 ± 4.8 years old) were conducted for 3 consecutive nights. Thirteen young males (20.9 ± 0.8 years old) were used as the control group. Compared with the young adults, the aged subjects showed extraordinary reductions in stages 3 and 4 sleep. In the young adults, the first four rapid eye movement (REM) periods showed progressive increases in length, whereas in the aged subjects, the same REM periods tended to decrease in length. In the young adults, the percentage of REM sleep increased during the second half of the night, whereas that of the aged subjects was fairly uniform throughout the night. The circadian rhythm of REM sleep for the aged persons apparently shifted, with the acrophase occurring during the first half of the night rather than in the early morning hours. **Key Words:** Polygraphic recordings—Aged persons—REM sleep—Slow-wave sleep.

Early studies of all-night sleep electroencephalograms (EEGs) of normal elderly persons were reported by Lairy et al. (1), Passouant et al. (2), and Roffwarg et al. (3). More recent reports are those of Agnew et al. (4), Kales et al. (5), Feinberg et al. (6,7,8), Kahn et al. (9,10), and Williams et al. (11).

The purpose of this study was to determine the sleep characteristics of neurologically and physically healthy aged persons by use of all-night sleep polysomnograms. Sleep of normal young males was recorded for comparison.

METHODS

Polysomnographic recordings of 15 aged persons (5 males and 10 females between 73 and 92 years of age; average age, 82.1 ± 4.8 years) living in the

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Yokufukai Nursing Home were made for 3 consecutive nights. Subjects had neither neurological nor physical disease. Lights were turned off at 2100 h and subjects slept until they awakened spontaneously.

A control group consisted of 13 normal young males between the ages of 19 and 22 (average, 20.9 ± 0.8 years). They were recorded from 2300 h until 0700 h in the sleep laboratory room at the Division of Psychophysiology, Psychiatric Research Institute of Tokyo. Sleep stages were scored according to the criteria of Rechtschaffen and Kales (12).

RESULTS

Because there was a pronounced first-night effect, second and third nights were evaluated (see Table 1).

Sleep stage percentages.

The following average percentages were recorded, respectively, for aged persons and young adults: wake stage, 27.0 ± 13.3 and 2.6 ± 2.6; stage 1 sleep, 15.7 ± 7.3 and 5.5 ± 2.3; stage 2 sleep, 40.5 ± 11.4 and 50.1 ± 5.2; stage 3 sleep, 2.1 ± 3.8 and 8.3 ± 4.3; stage 4 sleep, 0.3 ± 1.5 and 10.4 ± 5.1; rapid eye movement (REM) sleep, 14.4 ± 5.8 and 23.2 ± 3.9. The differences between these data were statistically significant ($p < 0.001$).

TABLE 1. *Comparison of sleep characteristics of healthy aged persons and healthy young adults during nights 2 and 3*

	Aged persons	Young adults
Number	15	13
Average age	82.1 ± 4.8	20.9 ± 0.8
Age range	73–92	19–22
SPT		
% Wake	27.0 ± 13.3	2.6 ± 2.6[a]
% REM	14.4 ± 5.8	23.2 ± 3.9[a]
% Stage 1	15.7 ± 7.3	5.5 ± 2.3[a]
% Stage 2	40.5 ± 11.4	50.1 ± 5.2[a]
% Stage 3	2.1 ± 3.8	8.3 ± 4.3[a]
% Stage 4	0.3 ± 1.5	10.4 ± 5.1[a]
Sleep latency (min)	39.8 ± 29.5	11.5 ± 9.1[a]
Number of state shifts	96.2 ± 26.8	59.0 ± 16.0[a]
Number of awakenings	21.0 ± 9.6	5.8 ± 3.4[a]
Length of REM periods (min)	81.4 ± 58.3	96.2 ± 44.9
SEI (TST/TIB)	66.6 ± 13.3	94.8 ± 3.8
Number of REM periods	4.1 ± 1.6	4.4 ± 0.8
Average SREM duration (min)		
1st sleep cycle	24.8 ± 12.3	15.1 ± 11.3
2nd sleep cycle	23.3 ± 10.6	28.8 ± 16.7
3rd sleep cycle	18.4 ± 10.1	30.2 ± 17.6
4th sleep cycle	22.5 ± 14.0	34.9 ± 18.7

SPT, sleep period time; SEI, sleep efficiency index (total sleep time/time in bed).
[a] $p < 0.001$, by t-test for the differences between the two groups.

Hourly percentages of sleep stages

The mean hourly percentage of stage 3 for the aged persons was 4% in the first hour of sleep, which decreased to 1% by the fourth hour. That of the young adults was 18% in the first hour of sleep; it also decreased (Fig. 1).

The mean hourly percentage of stage 4 for the aged persons was 0.7% in the second hour of sleep; this decreased to 0 to 0.2% during the night. The percentage for stage 4 sleep for the young adults was 36% in the first hour of sleep, and it showed a hyperbolic decline as the night progressed (Fig. 1).

For the aged persons, the mean hourly percentage of REM was fairly uniform, at 9% in the first hour of sleep, with an increase to 18% in the second hour that continued at 14 to 15% until the seventh hour. At that time, it increased again to 20%, only to decrease to 11% in the eighth hour. For the young adults, the mean percentage of REM appeared to increase almost continuously (Fig. 2).

The second and third nights' recordings of the 15 aged persons were used to make REM histograms (Fig. 3). This method also revealed that the percentage of REM was constant during the night.

Sleep onset latency, number of shifts of sleep stage, and number of awakenings

The average sleep onset latency in the aged subjects was 39.8 ± 29.5 min; in the control group the average was 11.5 ± 9.1 min. For the aged, the average number of shifts in sleep stage was 96.2 ± 26.8, whereas it was 59.0 ± 16.0 for the young subjects. The average number of awakenings was 21.0 ± 9.6 for the aged, and 5.8 ± 3.4 for the young. All of these differences were statistically significant ($p < 0.001$) (see Table 1).

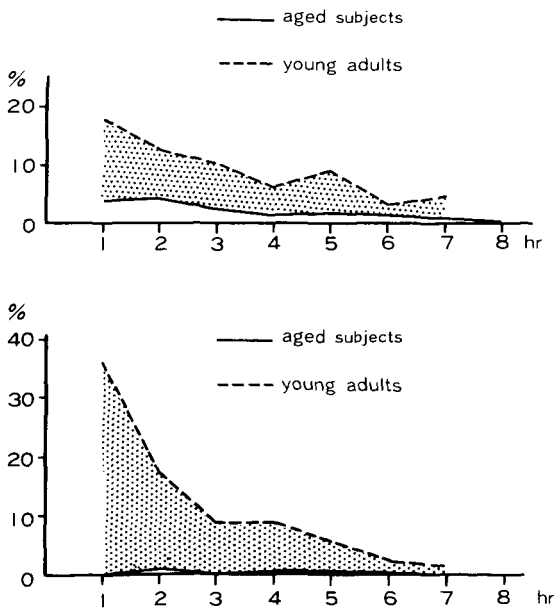

FIG. 1. Top: The hourly percentage of stage 3; **bottom:** the hourly percentage of stage 4. The young adults showed a very high percentage in the earlier part of the night, then a decrease along a hyperbolic curve. The percentages of stages 3 and 4 were low in the aged persons during the earlier part of the night, then decreased markedly.

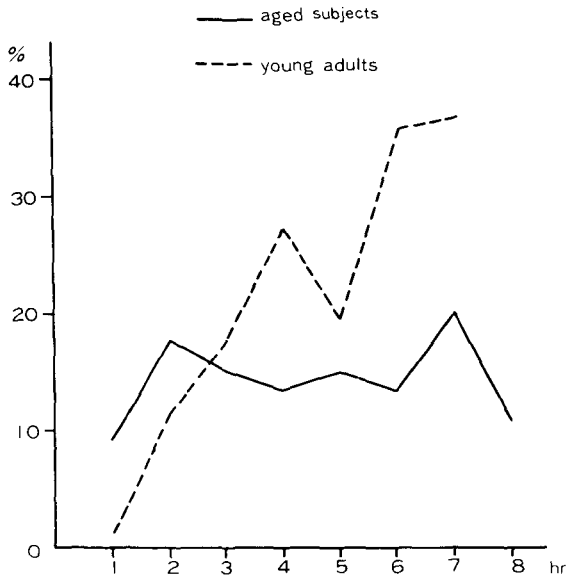

FIG. 2. Hourly percentage of stage REM. The hourly percentage of REM for the aged subjects was fairly uniform throughout the night, but that of the young adults appeared to increase almost continuously.

Number of REM periods

The mean number of REM periods was 4.1 ± 1.6 for the aged persons, and 4.4 ± 0.8 for the young adults, with no statistically significant difference ($p > 0.1$).

Length of REM periods

Figure 4 shows the length of REM periods in the intrasleep cycle. For the aged persons, there were 2 to 4 min (average, 3.1 min) of interruption time in each REM

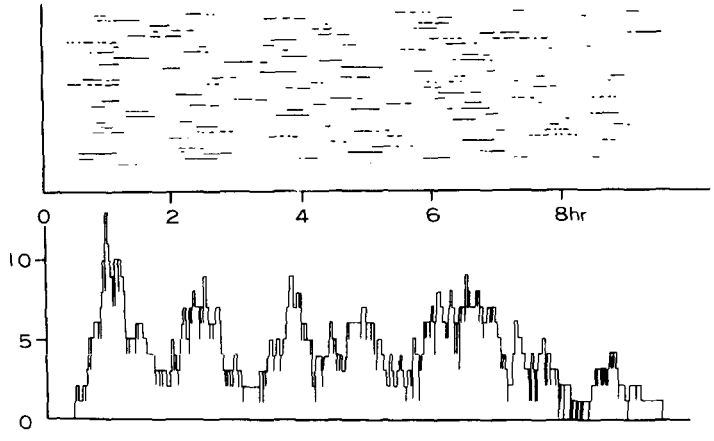

FIG. 3. Composite histogram of REM periods of the aged subjects for 30 nights. The second and the third nights of the 15 subjects are shown. **Top**: Bars indicate REM periods from onset of sleep. **Bottom**: Histogram of the REM periods. The *x* axis indicates the time from onset of sleep, and the *y* axis indicates the number of REM periods. There was an increase of REM sleep during the earlier part of the night, which then remained almost constant throughout the night.

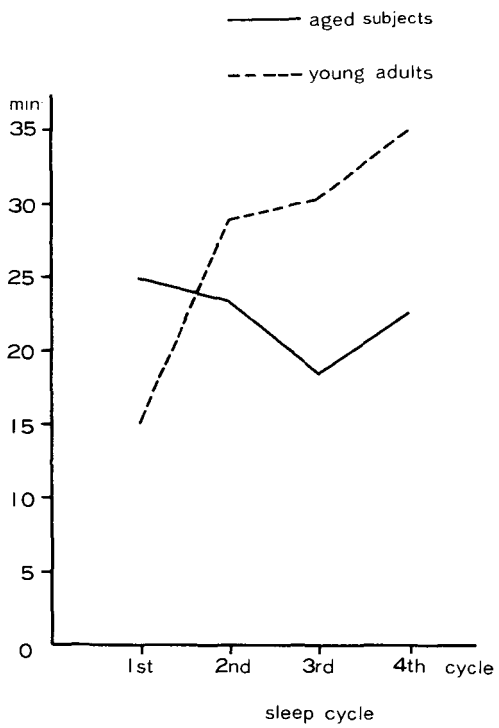

FIG. 4. Length of REM sleep periods. The average length of each REM period of the young adults increased progressively towards the end of the sleeping period, whereas that of the aged persons was long in the first cycle, then became short in the second and the third cycles.

period. We compared the durations of average REM periods between the two groups, including the interruption time for the first four periods. The durations for young adults appeared to increase successively; in the aged persons, they were, on the contrary, successively reduced.

REM density

The REM densities of the first four REM periods for aged persons were 32.5, 33.9, 32.8, and 40.9, respectively, showing a tendency to increase slightly during the second half of the night.

Sex differences in sleep of aged persons

We compared sleep characteristics of the five males (average age, 79 years) and the ten females (average age, 83.5 years) in this study. Sleep period time was 500.5 min for the males and 501.8 min for the females. The following percentages were recorded, respectively, for males and females: wake stage, 27.3 and 26.9; REM sleep, 12.2 and 15.5; stage 1 sleep, 20.0 and 13.5; stage 2 sleep, 40.5 and 40.6; stage 3 sleep, 0.1 and 3.1; stage 4 sleep, 0.0 and 0.5. These values showed no statistical significance ($p > 0.1$).

DISCUSSION

Regarding sex differences, males slept better in the studies of Kahn et al. (9,10), whereas females slept better in the study of Williams et al. (11); thus the results

were contradictory. We could not find significant sleep differences between males and females in this study, so we did not separate the data by sex.

Our data on the aged persons showed frequent shifts of sleep stages and numerous awakenings, a high percentage of wake stage, and a low percentage of slow-wave sleep (stages 3 and 4). These results confirmed the findings reported in the literature (9–11,13).

According to our results and those of previously published studies (4,5,9,11), the percentage of REM sleep had a tendency to decrease with an increase in average age. Kahn and Fisher (9) reported that the percentage of REM sleep was reduced during the aging process, but that REM sleep was maintained until late in the eighth decade, at which time a clear reduction occurred.

Our results concerning the length of REM periods in the intrasleep cycle agreed with previous studies (5,8,9) indicating that the first REM cycle was long. However, some differences emerged between our results and those of the previous studies in the comparison of the duration of average REM periods for the first four sleep cycles. In subjects in the sixth decade of life (7), the duration of REM periods increased during the night, having the same pattern as that of our young adults. In subjects in their eighth decade (5,8,10), an increase in REM duration occurred during the second half of the night, but this increase was slight compared with that of subjects in their sixth decade. In subjects in their ninth decade (9), the duration of REM periods tended to decrease in the second half of the night. Apparently, the duration of REM periods increased during the second half of the night in young subjects. With aging, however, the duration of REM periods tended to increase during the first half of the night and to decrease in the second half of the night. In aged persons, the hourly percentage of REM, as well as REM histograms, showed that the occurrence of REM was fairly uniform during the night. This pattern is obviously different from that of the young adults, and it may be related to the prolongation of REM sleep during the first half of the night and its reduction during the second half. These results suggest that the acrophase of the circadian rhythm of REM sleep for the aged persons was shifted to the earlier part of the night.

In the aged persons, REM periods were interrupted often by the wake stage, and 57% of the REM periods were followed by wake. According to the monoamine theory (14), when the catecholamine (CA) level in REM remains constant, REM persists for a long period, but when the CA level increases to a high level, REM changes to wake. High levels of CA may be one of the reasons for the frequent and long periods of wakefulness in aged persons.

Smith et al. (15,16) reported that the amplitude of slow waves during stages 3 and 4 decreases while the frequency may remain unchanged. However, in this study, the amplitude decreased and slow waves of less than 2 Hz did not appear continuously. The purpose of this study was to compare the sleep of the aged with that of the young. Thus we used the same criteria in the both groups.

In studies of aged persons (9, 10,11,13), the percentage of stage 3 varied from one study to another, but stage 4 percentages were consistently very low in all reports. In this study, about one-half of stage 3 + 4 sleep occurred during the first third of the night in both aged persons and young adults.

Some proposed mechanisms for reduced slow-wave sleep are disturbance of the serotonin mechanism in the raphe, disturbance of synchronization in the thalamus, and decrease of cerebral cortical cells. Hypofunction of the raphe in the midbrain might cause disturbance in the triggering of slow waves. However, slow waves not satisfying the criteria of stages 3 and 4 were observed among the aged persons. Thus, a defective trigger may not be the only cause of decreased slow-wave sleep in the aged.

The forward shift of REM sleep in the aged might be due to the marked reduction of slow-wave sleep in the earlier part of the night. This phenomenon may support a hypothesis that slow-wave sleep and REM sleep compete with each other with differing priorities (8,17).

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