Sleep Stage Characteristics of Long and Short Sleepers

Abstract. *The possibility of different sleep stage characteristics being associated with different sleep lengths was explored by comparing two groups of high school seniors, who characteristically slept 6½ hours or less or who slept 8½ hours or more, with an age-matched control group not selected on the basis of sleep length. All-night electroencephalography was used to examine the sleep stage characteristics of these groups. Compared with the unselected age-matched group, the short sleepers showed no significant diminution in their stage 4 (deep) or rapid eye movement (dream) sleep. The long sleepers were observed to obtain significantly more rapid eye movement sleep than did the other groups.*

Current sleep research has demonstrated that length of sleep is but a crude index of the sleep process. At least five characteristic patterns ("stages") of brain electric activity can be identified from electroencephalographic (EEG) recordings obtained during sleep (*1*). There are frequent changes from one to another of these stages throughout the night with individuals spending characteristic amounts of time in each of these stages (*2*).

A critical characteristic of the sleep period directly relevant to this paper is that stage 4 sleep occurs predominantly during the early part of the sleep period, whereas the stage of rapid eye movement (REM) is increasingly prominent in the latter part of sleep (see Fig. 1). As a result of this intrasleep cycling, reduction in the typical length of sleep results in the additional effect of selective sleep deprivation; that is, it results in differential deprivation of REM sleep with little or no reduction in stage 4 sleep. Several recent partial deprivation studies have been concerned with this problem (*3, 4*). These studies confirm that experimentally imposed limitations on sleep length result in substantial REM sleep deprivation.

Extending the length of the sleep period appears to have an opposite effect. Verdone found that the prolongation of sleep substantially increased the amount of REM sleep (*5*). We noted a similar effect in a study in which subjects were allowed to sleep as long as they wished after their normal sleep period had been shortened for 8 days (*3*).

In a general population of humans of the same age there is a wide range of individual differences in average sleep lengths. In a recent self-report survey of 2369 17-year-old students entering the University of Florida, for example, 8 percent reported sleeping less than 6½ hours per night and 13 percent reported sleeping more than 8½ hours per night. These naturally occcurring differences in sleep length raise a number of questions about the sleep stage characteristics associated with them. Do short sleepers miniaturize the sleep characteristics of the long sleepers? Are some stages of sleep reduced in short sleepers and others accentuated? More particularly, do short sleepers adapt their sleep process relative to the REM stage or are they relatively deprived of this stage by partial deprivation?

Two senior high school classes of the University of Florida laboratory school were administered a questionnaire about their sleep which included an item on sleep length. Subsequently, the students maintained a sleep log for 2 weeks in which they recorded their daily time of retiring and awakening. Two screening criteria were then introduced: (i) five successive nights of the sleep log entries in which the reported sleep length did not differ by more than 1 hour; (ii) a discrepancy of less than 1 hour between the questionnaire estimate of sleep length and the average of the five successive nights selected above. Subjects meeting these criteria and sleeping less than 6½ hours or more than 8½ hours were selected for further consideration. An independent estimate of the usual time of retiring and awakening of the subject was obtained from a parent or guardian. Again, a 1-hour discrepancy in estimated sleep length was used to eliminate subjects. From the remaining subjects, the long and the short sleepers meeting our 8½ and 6½ criteria were chosen. The selected subjects included six short sleepers (two males and four females) and eight long sleepers (four males and four females). Average lengths of sleep (from the sleep log) ranged in the short sleep group from 5 hours and 50 minutes to 6 hours and 25 minutes; in the long sleep group, from 8 hours and 40 minutes to 9 hours and 40 minutes. All subjects were between 17 and 19 years of age.

Table 1. The mean time spent in each stage of sleep after the onset of the first stage 1.

Stage	Duration (minutes) for		
	Long sleepers	Short sleepers	Control group
0	8	2	5
1	32	12	21
REM	155	96	101
2	277	168	215
3	22	18	29
4	72	81	81
Total	566	377	452

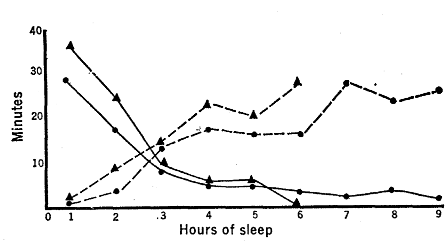

Fig. 1. Mean number of minutes of stage 4 and REM sleep by long and short sleepers. The solid line represents stage 4 sleep; the dashed line, REM sleep. Dots represent long sleepers; triangles, short sleepers.

The EEG sleep patterns of the subjects were recorded in the laboratory on three consecutive nights. They were asked to continue their daily routines but to report to the laboratory 1 hour prior to their usual bedtime. The wiring and recording procedures for subjects are described in detail elsewhere (*6*). The records for nights 2 and 3 were scored by 1-minute epochs for the Dement-Kleitman stages of sleep and for stage REM. Specifically, an epoch was scored as stage 4 if it contained 30 seconds or more dominated by 0.5 to 3.5 cycle/sec 40-microvolt (peak-to-peak) activity. The Dement manual was used as a guide in identifying REM periods (*7*). Sleep length in each instance was determined from the onset of the first stage 1 period to the onset in the morning of the first stage 0 period of 15 minutes or more in length.

For comparison a "control" group was drawn from a previously reported study (*8*). This group consisted of 14 males, 17 to 19 years of age, who were not selected on a sleep length criterion. Their data are the second and third nights of experimentally uninterrupted sleep in the same laboratory, recorded and scored by the same procedures.

Table 1 displays the number of minutes slept in each sleep stage by the long sleepers, the short sleepers, and the control group. Figure 1 presents the hour-by-hour mean number of minutes of stage 4 and stage REM for the experimental groups.

Both experimental groups differed significantly from the control group in total time slept ($P < .01$). The shortest mean sleep length for the long sleepers was 529 minutes; the longest mean sleep length for the short sleepers was

395 minutes. The short sleep group had less sleep in combined stages 0 and 1 than the long sleepers ($P < .01$) and probably less than the control group ($P < .05$). They had less stage 2 sleep than either the long sleepers or the control group ($P < .01$), and less stage 3 sleep than the control ($P < .01$). The long sleepers had more stage REM and stage 2 sleep than either the short sleep group or the control group ($P < .01$). They probably had more combined stage 0 and stage 1 sleep than the controls ($P < .10$). The short sleep group did not differ statistically from the control group in stage 4 and stage REM. The long sleep group did not differ from either the control group or the short sleep group in stage 4 sleep. All statistical tests are two tail tests of the *t*-test for independent means.

Subjects selected on the basis of naturally occurring long and short sleep patterns gave evidence of different kinds of sleep processes when these processes were measured in the laboratory and indexed by EEG sleep stages. Short sleepers showed a pattern that may be interpreted as more "efficient." Less time was spent in light sleep and awakenings. Their reduced stage 3 suggests that they made the transition from stage 2 to stage 4 more readily, since stage 3 is essentially a mixed stage 2 and stage 4 record. They received as much stage 4 or REM sleep, generally considered as need states, as did the unselected sleepers, although they slept 1 hour and 15 minutes less. On the other hand, the long sleep group showed marked increases in REM sleep and in stage 2 sleep when compared with the control group, increases of 53 and 36 percent, respectively. The large relative increase in stage REM would reflect a continuation of the intrasleep cycling previously noted, in which REM occurs as a prominent aspect of the later part of the natural sleep process.

Jones and Oswald have recently reported the sleep stage characteristics of two subjects who had consistently slept only about 3 hours per night over a long period of time (*9*). In both cases the absolute amount of stages 3 and 4 constituted approximately 50 percent (80 to 90 minutes) of sleep periods that averaged 165 minutes; REM sleep, on the other hand, occupied only about 40 minutes of the sleep periods. These data indicate that there is a point at which shortening of the total time available for sleep will result in REM restriction in chronic sleep patterns.

Both our data and those of Jones and Oswald support a hypothesis that the absolute amount of REM will be a function of the length of time of the sleep period. In order of sleep length the average amounts of REM in the four populations examined were: 2 hours and 45 minutes sleep, 48 minutes REM (see *9*); 6 hours and 17 minutes sleep, 96 minutes REM (short sleepers); 7 hours and 32 minutes sleep, 101 minutes REM (control group); and 9 hours and 26 minutes sleep, 155 minutes REM (long sleepers). There is some evidence to support the hypothesis that initial "strength" of the stage 4 response is a function of the time between sleep periods. It has been previously noted that a strong stage 4 response is typical of total deprivation conditions exceeding 24 hours (*10*). In the Jones and Oswald study, stages 3 and 4 constituted 50 percent of sleep with 21 hours between sleep periods. This tendency for a potent stage 4 response had been noted in a study of partial sleep deprivation in which sleep was restricted to 3 hours per night (and hence 21 hours between sleep periods) (*3*); stage 3 and 4 sleep constituted 55 percent of the 3 hours. Compared with the long sleepers, the short sleepers of this study (with a longer time between sleep periods) showed a higher stage 4 response in the early part of the night (Fig. 1).

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Hormonal Effects on Ontogeny of Swimming Ability in the Rat: Assessment of Central Nervous System Development

Abstract. *The maturation of swimming behavior and the evoked cortical response to sciatic stimulation were studied in newborn rats receiving thyroxine or cortisol. Compared to that of controls the maturation of swimming is accelerated or delayed 2 to 3 days by thyroxine or cortisol treatment, respectively, and this corresponds to ontogenetic shifts in the characteristics of the evoked potential. Front leg movement during swimming normally diminishes at about 16 days of age and is inhibited by day 22. Thyroxine also advances and cortisol delays the age at which this inhibitory mechanism becomes evident, and compresses (thyroxine) or expands (cortisol) the time interval over which it becomes functional. During early postnatal life certain circulating hormones can affect the rate and chronology of central nervous system maturation. Swimming behavior may be a simple model to use in studies concerned with factors affecting the functional and behavioral development of the central nervous system.*

At birth the rat is a very immature organism, and many of the coordinated physiological mechanisms so essential for adult survival do not function effectively (*1*). In addition to perinatal homeostatic immaturity, numerous adult behavioral adaptive mechanisms also develop slowly; for example, the infant rat exhibits no startle reflex (*2*) or righting reflex (*3*). In experiments designed to study learning ability in the infant rat we accidentally observed that, for the first 10 days of life, the infant rat was unable to swim with a coordinated capability. We have found no systematic reports on the maturation of swimming ability in the laboratory rat (*4*).

We have observed (*5*) that administration of thyroxine to the newborn rat accelerated biochemical, neurophysiological, and behavioral development of the central nervous system (CNS), whereas administration of cortisol delayed CNS development. Swimming represents an adaptive response to a life-threatening situation that requires the smooth integrated organization of a co-