Sleep Patterns of Pubertal Males

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Extract

Comparisons of three groups of normal subjects between the ages of 8 and 31 years, all of whom were studied under similar conditions, revealed certain common sleep characteristics. During the second and third decades of life, normal sleep is characterized by a concentration of *stage 4* during the first third of the night and of *stage 1-REM* during the last third; and, during the first part of the night, by a progression from wakefulness down through *stage 4*. Percentages of *stages 0, 1, 1-REM*, and *3* do not differ significantly among age groups. There are, however, a significant increase in *stage 2* and a significant decrease in *stage 4* between the ages of 15 and 20 years.

Speculation

The psychopathologic problems of adolescence may be related to qualitative changes in sleep patterns. An understanding of adolescent psychologic problems may be aided by further study of their relation to sleep changes and corresponding changes in human growth hormone.

Introduction

The nature and function of sleep and dreaming have inspired interest and curiosity throughout history. But it was not until this century that technologic advances made it possible to investigate the psychobiology of these processes.

The development of the electroencephalograph (EEG) by Berger in 1924 [4], and the use of this device by Loomis and associates [19] to identify distinct patterns of electrophysiologic activity during sleep, created new possibilities for the investigation of sleep. Utilizing these new techniques, Aserinsky and Kleitman [3] found that human sleep is characterized by regularly recurring periods of rapid conjugate eye movement (REM). It has also been shown that most dreaming occurs during these periods [3, 5].

The effect of growth, development and aging on human sleep patterns has recently produced considerable scientific interest. Studies in our laboratory of

two-year-olds [18], preadolescent males [22], 20- to 30-year-old males and females [24, 25], and 50- to 60-year-old males [2] show similarities among individuals in a given age group, and striking differences between age groups.

Feinberg [7] has theorized that the decline in *stage 4* may be associated with a decline in cognitive ability, beginning perhaps as early as age twenty. Roffwarg *et al.* [21] attribute the *stage 1-REM* decrease to a reduced need for the endogenous stimulation provided by REM sleep.

Other studies in our lab on depressed patients [9], post-partum women [15], angina pectoris patients [16], and patients with kidney failure [13] have indicated that psychiatric and physical problems are accompanied by changes from the normal sleep pattern. However, Feinberg [7] suggests that changes in sleep characteristics produced by aging "far exceed in magnitude those produced by any pathological condition compatible with life."

In reports that have compared sleep characteristics of different age groups, the period of puberty has been neglected. Yet the psychobiologic processes which undergo rapid change during puberty may significantly affect sleep patterns; for example, sex hormone release affects sleep [10, 17], and blood serum levels of human growth hormone appear to be related to *stage 4* sleep [11]. Both of these hormones are involved in the psychobiologic changes of puberty. Therefore this study reports the sleep pattern for pubertal males, and compares it with sleep patterns for a group of prepubertal (8- to 11-year-old) and a group of postpubertal (20- to 30-year-old) males.

Subjects and Method

The subjects were 10 white male high school students in good health, who ranged in age from 12.8 to 15.3 years (mean 14.6). A physical examination conducted 1 year before the sleep recordings revealed that none of the subjects had completed pubertal growth, as defined by Donovan and Van Der Werff Ten Bosch [6] and characterized primarily by the development of primary and secondary sex characteristics, such as enlargement of the gonads and development of body hair. At the time of the sleep recordings, all subjects had pubertal growth according to these criteria.

Each subject slept three consecutive nights in the laboratory. He went to bed and arose in the morning according to his normal sleep habits. The first night was considered an adaptation night; therefore, first night data have not been included in the analysis. Data for the second and third nights were averaged, except where noted, and the means for each subject were averaged to obtain group means.

Electrode placement, recording technique, and scoring procedures were the same as reported by Williams *et al.* [24] including as the criterion for delta wave amplitude: peak to peak, 40 μ V.

Results

All of the values reported below, except where noted, were computed on the basis of the *sleep period*, which is defined as the total time in bed minus any *stage 0* prior to sleep onset and/or after the final morning awakening.

First Night Effect

To determine whether pubertal males experienced the "first-night effect" reported for other subjects [1, 20], four variables for the first night were compared

with those for the subsequent nights. These were: sleep period time (SPT), as defined above; total sleep time (TST), which is the total time in *stages 1, 1-REM, 2, 3, and 4*; the ratio of *stage 1-REM* sleep to non-REM (NREM) sleep; and the sleep efficiency index, which is the ratio of TST to time in bed (TIB). For all of these measures, the first night values (467.50 min, 438.20 min, 0.31, and 0.86 respectively) were significantly lower ($P < 0.05$ in all cases) than values for the later nights (495.65 min, 489.85 min, 0.38, and 0.96 respectively).

Basic Sleep Variables

In Table I are listed the mean percentage for each sleep stage, the TST, and the sleep efficiency index for each subject and for the group. The highest percentage (43.92%) of time was spent in *stage 2*, the lowest (1.16%) in *stage 0*. *Stage 1-REM* averaged 26.97% of the sleep period and *stage 4*, 18.10%. The small standard deviations indicate the narrow range of individual differences.

Average TST was 489.85 min, and the average sleep efficiency index was 0.96.

Stage Characteristics

Table II presents averages for four characteristics of the individual sleep stages: latency to the onset of each stage from the onset of the first sleep stage; frequency of occurrence of each stage; number of awakenings from each stage, including the final morning awakening; and average duration of each stage within the sleep period.

Subjects averaged 12.70 min in bed before entering the first sleep stage, which is shown as *stage 1* latency since these subjects always started their sleep with *stage 1*. The rest of the latencies show that during the first part of the night, sleep typically progressed from *stage 1* through *stage 4*, after which *stage 1-REM* was entered. *Stage 0* was the last stage to appear.

Stage 2 occurred most frequently (15.15 times). *Stages 3, 1, 1-REM, 4, and 0* occurred with decreasing frequency. There was a group average of 45.50 stage shifts per night.

Subjects averaged 4.40 awakenings, most of which were from *stage 2*. *Stages 1-REM, 4, and 2* lasted a relatively long time when they occurred, whereas *stages 0, 3, and 1* were of short duration.

REM Sleep

The mean length of REM periods (excluding those terminated by the final morning awakening) was 30.26

Table I. Basic EEG sleep pattern variables for 13- to 15-year-old males

Subject	Stage as % of sleep period time ¹						TST ²	Sleep efficiency index ³
	0	1	1-REM	2	3	4		
1	0.60	1.74	27.74	45.92	3.62	20.38	481.00	0.94
2	0.21	3.26	28.57	35.82	7.99	24.16	475.00	0.97
3	1.85	4.61	23.26	50.76	5.42	14.08	480.00	0.95
4	0.49	1.69	28.19	43.94	6.76	18.91	499.50	0.96
5	0.80	4.29	28.00	39.60	3.80	23.50	496.00	0.95
6	1.55	5.69	23.37	49.49	3.60	16.28	514.00	0.97
7	0.10	3.09	32.54	39.95	8.96	15.34	485.00	0.99
8	0.83	3.09	25.56	51.00	5.92	13.59	479.00	0.96
9	3.37	7.00	25.07	41.23	3.64	19.70	493.00	0.92
10	1.78	3.46	27.38	41.51	10.80	15.06	496.00	0.97
Mean	1.16	3.79	26.97	43.92	6.05	18.10	489.85	0.96
SD	1.00	1.66	2.77	5.22	2.55	3.81	12.02	0.02

¹ Time from sleep onset to morning awakening.² Total sleep time: sleep period time minus any *stage 0* during the night.³ Ratio of total sleep time to time in bed.Table II. Characteristics of individual sleep stages for 13- to 15-year-old males¹

Sleep stage	Latency to onset, min ²		Frequency of occurrence		Number of awakenings		Average duration, min	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	290.00	126.65	3.40	2.88			1.63	0.67
1	12.70	7.62	7.70	3.33	1.15	1.20	2.57	0.67
1-REM	129.75	31.26	5.85	1.27	1.05	0.76	24.42	4.66
2	4.65	1.93	15.15	2.53	2.05	2.13	14.86	2.16
3	12.40	2.91	9.20	2.16	0.05	0.16	3.19	0.90
4	15.75	3.74	5.20	1.48	0.10	0.32	18.87	6.54
All stages			46.50 ± 7.98		4.40 ± 2.88			

¹ Values are the averages for 10 subjects.² For *stage 1*, this is the same as sleep latency. For the other stages, latency is figured from the onset of *stage 1*.

min. All subjects had at least four REM periods on both nights. The interval between REM periods averaged 60.81 min, and the average length of the REM cycle (time from start of one REM period to start of the next) was 91.08 min.

Sequence of Sleep Stages

The most frequent stage shifts were from *stage 1* to *stage 2* (13.99%), from *stage 2* to *stage 3* (12.87%), from *stage 2* to *stage 1-REM* (12.00%), and from *stage 3* to *stage 4* (11.73%). If shifts to or from *stage 1-REM* are disregarded, 43.92% of the total number of shifts were in a downward direction, while 30.19% were in an upward direction. The progression downward was smoother than the ascension from *stage 4*.

Distribution of Sleep Stages

Table III shows the time spent in each stage for each third of the night as a percentage of the stage

total. *Stage 0* (63.62%) and *stage 1-REM* (53.14%) were concentrated in the last third of the night, and both increased smoothly from low percentages in the first third of the night. *Stages 3* (62.23%) and *4* (80.23%) were concentrated in the first third of the night. *Stage 1* decreased during the second third, while *stage 2* increased during that period.

Table III. Sleep stages during the night for 13- to 15-year-old males¹

Sleep stage	Third of the night		
	First	Second	Last
0	8.14	28.23	63.62
1	34.38	18.24	47.38
1-REM	8.56	38.30	53.14
2	26.38	41.07	32.55
3	62.23	23.43	14.34
4	80.23	15.14	4.63

¹ Values, in per cent, are the averages for 10 subjects.

Sleep in Three Age Groups

The sleep characteristics of pubertal males were compared with those of 18 preadolescent [22] and 16 young adult [24] males observed under similar conditions.

Sleep Stage Percentages. Table IV shows the mean stage percentages for each of the three age groups. Stages 2 and 4 were significantly different among the three groups: the young adults had a greater percentage of stage 2 and a smaller percentage of stage 4 than both younger groups. There was no difference in the percentage of stage 1-REM among the three groups.

In none of the three groups was stage 3 ever preceded by stages 0, 1, or 1-REM, and stage 4 never followed these stages or stage 2 in the two younger groups. In the young adults, there were 2 shifts from stage 2 to stage 4. In all groups, stage 1-REM was most often preceded and followed by stage 2. The ascension from stage 4 was less smooth in all groups than the progression downward. All exhibited a slightly greater tendency to awake from stage 4 than from stage 3. In each group, the probability of shifting to stage 4 from stage 3 was greater than that of shifting from stage 3 to stage 2, but, with increasing age, these two probabilities became similar.

Distribution of Sleep Stages. All groups had between 50% and 60% of stage 1-REM concentrated in the last third of the night, and all showed a progressive increase to this level from the first third of the night. All groups had the highest percentage of stage 2 in the second third of the night. The three groups had 55–62% of stage 3 and 73–80% of stage 4 during the first third of the night. The occurrence of both of these stages decreased progressively through the last

third of the night. The distributions of stages 0 and 1 were not consistent among the three groups, although the preadolescent and young adult males were similar in their distribution of stage 1.

Discussion

The concentration of stage 4 during the first third of the night and of stage 1-REM in the last third has been reported [12, 24].

The lack of change in percentage of stage 1-REM across the three age groups was unexpected since several investigators have reported that stage 1-REM changes as a function of age. Feinberg and Carlson [8] found that the absolute amount of combined stages 1 and 1-REM decreased sharply between the ages of 6 and 21 (168 and 97 min respectively, as interpolated from a graph), after which it remained fairly constant until extreme old age. Roffwarg *et al.* [21] indicate that between the ages of 5 and 13 years, REM constitutes 18.5% of total sleep and that it increases to 20% and 22% in 14- to 18- and in 19- to 30-year-olds respectively. Our data indicate that the REM percentage of the sleep period does not change significantly across this 20-yr span. The differences in these studies may result from the fact that both Feinberg and Carlson [8] and Roffwarg *et al.* [21] studied rather small numbers of subjects in each age group, and included both males and females in some of their groups. This suggests the interesting possibility that there is a sex difference in sleep patterns even at this early age. Our data are from groups of at least 10 subjects each, all of whom were males. Different TST's among groups and studies can account for absolute REM time differences, but this would not affect the REM percentages. There are also differences in the scoring used in this laboratory and in those cited. However, differences are constant for any one laboratory across all ages studied by that laboratory and therefore would not account for the fact that one investigator finds a REM difference *between his own groups of subjects* while another investigator does not find differences *between his own groups*.

In contrast to stage 1-REM, stage 4 appears to be significantly reduced with increasing age, although this decrease is not progressive. Both the absolute and relative amounts of stage 4 were similar in our groups of 8- to 11- (101.2 min = 17.9%) and 13- to 15-year-old males (89.6 min = 18.1%), but there was a reduction in both values between puberty and the third decade (53.8 min = 13.2%). These amounts are similar to a

Table IV. Stages of sleep for pre-adolescent, pubertal, and young adult males¹

Stage	Preadolescent (8–11 yr)	Pubertal (13–15 yr)	Young adult (21–31 yr)	Significance ²
0	1.5	1.2	0.9	NS
1	6.1	3.8	5.4	NS
1-REM	24.3	27.0	24.1	NS
2	44.2	43.9	48.7	$P < 0.05$
3	5.9	6.1	7.7	NS
4	17.9	18.1	13.2	$P < 0.05$

¹ Values, in per cent, represent means for 18, 10, and 16 subjects respectively.

² Significance for differences among the groups. ANOVA for stages 0, 1-REM, 2, and 3; Kruskal-Wallis for stages 1 and 4. NS: not significant.

previous finding [18] that two-year-old children average 105.3 min (17.6%) of *stage 4*. (This figure is slightly inflated due to the inclusion of some *stage 3*.) Feinberg and Carlson [8] suggest that the absolute amount of *stage 4* sleep is a hyperbolic function of age, *i.e.*, it decreases sharply through the third decade and then decreases more gradually. Therefore, we would expect *stage 4* to change significantly between 8 and 15 years, but this was not the case. Our data indicate that the sharp decrease in *stage 4* may not begin until late adolescence. Since decreases in *stage 4* sleep are known to accompany emotional disturbances such as depression [9], a complete description of the changes in *stage 4* which occur during adolescence may contribute to our understanding of the adolescent emotional problems.

Understanding of adolescent psychological problems may be further aided by clarification of the relation between *stage 4* and concentrations of human growth hormone (HGH). Levels of HGH are high during infancy and childhood and begin to decrease with increasing age; thus the pattern is the same as that we have found for *stage 4* sleep. In addition, recent studies [11, 14, 23] have indicated that the peak daily HGH concentration is related to the occurrence of *stage 4*. This relation may provide a useful physiologic variable with which to explore the nature and function of *stage 4* sleep and related phenomena in pubertal subjects.

Conclusions

The sleep patterns of pubertal males, when compared with a prepubertal group and a young adult group, show no large differences except in the percentages of *stages 2* and *4*. In both of these stages, the two younger groups were significantly different from the older group, with the younger males having less *stage 2* and more *stage 4* than the older subjects. The percentage of REM remained unchanged across all groups.

Since the *stage 4* decrease apparently occurs sometime between early adolescence and adulthood, a correspondence with change in HGH level and with psychologic adjustment is suggested.

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