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Level of Sleepiness and Total Sleep Time Following Various Time in Bed Conditions

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Summary: The effects of various time in bed (TIB) conditions on daytime sleepiness and total sleep time (during a 24-hour enforced bedtime) were investigated. Thirty-two healthy male subjects participated in the study. Subjects were assigned to one of four groups to balance average screening multiple sleep latency tests (MSLT). Subjects were randomly assigned to spend 8, 6, 4 or 0 hours time in bed. They underwent the same TIB condition twice with at least 7 days between the two sessions. Following their assigned time in bed conditions, subjects were counterbalanced to have a standard MSLT and a 24-hour enforced bedtime protocol. To assess the effect of TIB on the MSLT, the sleep latencies were submitted to a four (TIB condition) by four (nap test) multivariate analysis of variance. The sleep latencies were shorter for those subjects in the 0-hours condition when compared to the other three conditions. Also, the sleep latencies of those subjects in the 4- and 6-hour conditions were comparable but different from those of subjects in the 8- and 0-hour TIB conditions. To assess the effect of TIB on the 24-hour enforced bedtime, the total sleep time during this period was submitted to a six (4-hour block) by four (TIB condition) multivariate analysis of variance. Subjects slept more following 0 hours TIB when compared to the other three conditions. There were no statistically significant differences between the 8-, 6- and 4-hour TIB conditions. Across conditions, subjects slept more during the first 4 hours when compared to blocks 2, 3, 4 and 5. Blocks 1 and 6 were comparable. Subjects slept more in block 2 when compared to blocks 3 and 4 but less when compared to block 6. Subjects' sleep was comparable in blocks 3 and 4 but less when compared to blocks 5 and 6. Subjects slept less in block 5 when compared to block 6. Finally, trend analyses were used to better define the quantitative characteristics of the mean MSLT and total sleep times following the various TIB conditions. A significant linear component but no quadratic or cubic components were evident in the mean MSLT and total sleep times with decreasing TIB. These results suggest that the propensity to fall asleep and the propensity to stay asleep follow similar response patterns. **Key Words:** Sleepiness—Total sleep time—Multiple Sleep Latency Test (MSLT)—Sleep deprivation.

The consequences of daytime sleepiness have been increasingly recognized as a public health issue (1–3). Among the determinants of daytime sleepiness, sleep loss is probably the most frequent cause in the general population (4,5). The multiple sleep latency test (MSLT) has enabled the quantification of the effects of sleep loss on the propensity to fall asleep (6–8). These studies indicate that the degree of daytime sleepiness is directly related to the amount of nocturnal sleep (9,10). Increasing amounts of sleep loss are followed by increasing levels of daytime sleepiness. Conversely, studies in which sleep times have been increased have documented reductions in pre-existing levels of sleepiness. These MSLT studies suggest there is a homeostatic balance in sleep/wake function.

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Research on recovery sleep has documented only a 10–20% lengthening of sleep time following the loss of one night of sleep (11,12). These studies utilized extended recovery periods (8–12 hours) or ad libitum sleep periods and failed to demonstrate a relation between the amount of sleep loss and the amount of recovery sleep. In contrast to these studies, research utilizing enforced bedrest periods (13,14) have indicated that subjects are capable of accruing sleep during the day when left undisturbed. However, these studies did not control for level of preexistent sleepiness. Thus, these data can only be utilized to a limited extent in deriving information on the homeostatic balance in sleep/wake function. More recently, a 24-hour enforced bedtime protocol, similar to the one used by Aserinsky (13) to measure the maximal capacity for sleep, was utilized to more accurately determine the extent of sleep recovery (15). This particular methodology minimizes the impact of possible confounding

variables such as subject motivation in the ad libitum sleep protocols and early termination of recovery sleep in the slightly extended time in bed (TIB) protocols. By using the 24-hour enforced bedtime methodology it has been shown that 72% of lost sleep is recovered following one night of sleep deprivation. Thus, the 24-hour enforced bedtime method showed that a greater amount of sleep is recovered following sleep deprivation than previously believed. It also makes the 24-hour bedtime protocol a viable methodology for further studies of sleep homeostasis.

An area of particular relevance to the understanding of sleep/wake function, and one not yet fully understood, is whether a parametric reduction of prior sleep time results in comparable patterns in the propensity to fall asleep as measured by the MSLT and to stay asleep as demonstrated by the amount of recovery sleep. Thus, the purpose of this study was to determine the effects of 8, 6, 4, and 0 hours TIB on daytime sleepiness and total sleep time during a 24-hour enforced bedtime.

METHODS

Subjects

The subjects were 32 male nonsmoking volunteers, ages 20–35. The subjects had a regular nocturnal sleep schedule, no history of drug abuse, medical or psychiatric disorders. All subjects signed an informed consent and were paid for their participation in the study.

Procedure

The subjects were given a physical examination, and urine was collected for toxicology screening before entering the study. Subjects underwent a screening nocturnal polysomnography (2330–0730 hours) including an electroencephalogram (EEG), an electrooculogram (EOG) and an electromyogram (EMG) and a nasal/oral thermistor and EMG leg electrodes to screen for apnea and periodic leg movements. A sleep efficiency of at least 88% and no evidence of periodic leg movements during sleep, sleep disordered breathing or indication of other pathologies during sleep were required for entry to the study. For all the subsequent polysomnographic recordings, electrodes were attached to record EEG, EOG and EMG only.

The day following the screening polysomnogram, subjects were tested for level of sleepiness using standard MSLT procedures. For the MSLT, subjects were instructed at 1000, 1200, 1400 and 1600 hours to lie down on a bed in a quiet, darkened bedroom and try to fall asleep. Standard EEGs, including an occipital placement (Oz), EMG and EOG, were recorded during the naps. Each nap test lasted 20 minutes if sleep did not occur. If sleep occurred, the nap was terminated after three episodes of stage 1 nonrapid eye movement (NREM) sleep or the first epoch of any other stage of sleep. Sleep latencies were defined as the time to the first epoch of any stage of sleep. Subjects were instructed not to fall asleep between naps and were monitored by technicians to assure wakefulness. To qualify for participation in the study, subjects had to have a mean MSLT of ≥ 8 minutes and no sleep onset rapid eye movement (REM) periods.

Those subjects passing the screening were assigned to one of four groups by matching subjects for their screening mean MSLT. Then, each group was randomly assigned one of four time in bed (TIB) conditions [8 (control), 6, 4 and 0 hours].

Subjects underwent the same TIB condition twice with at least 7 days between the two test sessions. Subjects were instructed to follow a regular sleep schedule while at home. Those subjects in the 0-hours TIB condition did not go to bed. Subjects in the 8-, 6- and 4-hour TIB conditions had bedtimes at 2330, 0130 and 0330 hours, respectively. Subjects were monitored to assure compliance with the experimental protocol and were offered snacks before their assigned bedtime. No caffeinated beverages or excessive exercise were allowed during the entire time in the laboratory. Once in bed, subjects were polysomnographically recorded for the entire sleep period. An extra half an hour was allowed to compensate for wake time in the 8-, 6- and 4-hour TIB conditions.

Following their assigned TIB, subjects underwent either a 24-hour bedtime protocol or a standard MSLT. The order of the two assessments was counterbalanced. The MSLT times and procedures were the same as those described for the screening MSLT. The 24-hour bedtime protocol started at 0800 hours and lasted until 0759 hours the next day. Subjects were required to remain in bed in a darkened bedroom with provisions for toileting and meals made according to the following schedule. Food was offered at three specified times and only if subjects were awake (0700–0900, 1200–1430 and 1800–2030 hours). Subjects had to awaken spontaneously and stay awake for 10 minutes before food was offered. If subjects were asleep, the meal was delayed until the next specified meal period. The food offered at each meal consisted of a sandwich, fruit and a noncaffeinated beverage. Thirty minutes were allowed for the consumption of food except for the 1800–2030 period, which was extended to 45 minutes to allow for the replacement of electrodes. Subjects remained in their rooms during the consumption of their meal, but were allowed to get out of bed, sit at a table and use the restroom. Subjects remained in bed with lights off and were polysomnographically recorded the

TABLE 1. *Mean (standard deviation) of sleep latencies on the MSLT following 8, 6, 4 and 0 hours time in bed (TIB)*

TIB	Nap 1	Nap 2	Nap 3	Nap 4	Mean
8 hours	12.19 (5.87)	11.19 (7.57)	11.13 (5.81)	15.25 (5.31)	12.44 (3.81)
6 hours	9.56 (6.65)	7.50 (6.01)	8.50 (7.28)	8.19 (4.46)	8.44 (3.31)[a]
4 hours	6.38 (3.35)	7.13 (5.05)	7.44 (4.81)	7.13 (5.87)	7.02 (3.50)[a]
0 hours	2.13 (1.81)	1.44 (1.15)	1.81 (1.10)	2.13 (0.92)	1.88 (0.72)[b]
x̄ Nap	7.56 (5.97)	6.81 (6.30)	7.22 (6.08)	8.17 (6.44)	

[a] Posthoc comparisons of significant main effect of TIB ($p < 0.05$): vs. 0, 8 hours TIB.
[b] Posthoc comparisons of significant main effect of TIB ($p < 0.05$): vs. 8, 6, 4 hours TIB.

rest of the time. Subjects were not allowed watches or alarm clocks in their rooms and their interaction with laboratory personnel was limited to the meal periods. An additional 15-minute bathroom break, between 2300 and 0100 hours was provided. At other times use of the bathroom was allowed only if the subject had been awake for 10 minutes or longer.

Polysomnographic recordings were scored in 30-second epochs according to the standards of Rechtschaffen and Kales (16) by scorers blind to the experimental condition. The inter-rater reliability was maintained at 90% or higher. Data were analyzed using the general linear model analysis procedure (SAS Institute). The probabilities reported are corrected by the Greenhouse-Geisser method. Posthoc contrasts were done using Duncan's procedure.

RESULTS

Baseline sleep-wake function

The total sleep times (TSTs) on the screening polysomnograms were comparable among the four conditions (448 ± 22 minutes for the 8-hour TIB condition; 454 ± 10 minutes for the 6-hour TIB; 448 ± 16 minutes for the 4-hour TIB and 445 ± 14 minutes for the 0-hours TIB). Likewise, the screening mean sleep latency on the MSLT was comparable among the four conditions (12.30 ± 2.44 for the 8-hour TIB; 10.24 ± 2.10 for the 6-hour TIB; 11.30 ± 2.91 for the 4-hour TIB and 10.80 ± 2.62 for the 0-hours TIB).

Sleep during the TIB conditions

Those subjects in the 0-hours TIB condition were not allowed to sleep and, thus, their sleep time was zero. A two factor multivariate analysis of variance (MANOVA) (between-group factor: 4-, 6- and 8-hour TIB; and within-group factor: sleep time the night before MSLT and before 24-hour enforced bedtime) was carried out to compare the total sleep times among TIB conditions before each assessment. There was a main effect of TIB (df = 2,21; $F = 239.18$; $p < 0.01$) but no main effect of night (df = 1,21; $F = 0.36$; ns) or TIB by night interaction (df = 2,21; $F = 0.26$; ns). Posthoc comparisons showed that subjects slept significantly ($p < 0.05$) more in the 8-hour TIB condition (429.63 ± 42.05 minutes) when compared to the 6- and 4-hour TIB conditions (336.09 ± 18.33 minutes and 232.44 ± 6.61 minutes, respectively). The 6- and 4-hour TIB conditions were also significantly different from each other ($p < 0.05$).

Sleepiness

The effect of TIB on the MSLT was evaluated. A four (TIB condition) by four (time of test) MANOVA was carried out to compare the four sleep latencies among the experimental conditions (Table 1). There was a main effect of TIB (df = 3,28; $F = 15.96$; $p < 0.01$). Posthoc comparisons showed that subjects in the 0-hours TIB condition had significantly ($p < 0.01$) shorter latencies on the MSLT when compared to the subjects in the 4-, 6- and 8-hour TIB conditions. Also, the MSLT of those subjects in the 4- and 6-hour TIB conditions were comparable but significantly ($p < 0.05$) different from that of subjects in the 8- and 0-hours TIB. No main effect of time of test (df = 3,84; $F = 0.50$; ns) or TIB by time of test interaction (df = 9,84; $F = 0.44$; ns) was demonstrated.

Recovery sleep time

To evaluate the pattern of recovery sleep, the 24-hour enforced bedtime was divided into six (4-hour) blocks (Table 2). Thus, the blocks represent clock hours 0800–1159 (block 1), 1200–1559 (block 2), 1600–1959 (block 3), 2000–2359 (block 4), 2400–0359 (block 5) and 0400–0759 (block 6). To assess the differential effects of TIB, the total sleep time on the 24-hour recordings were submitted to a four (TIB condition) by six (4-hour block) MANOVA. The results of this analysis showed a significant main effect of TIB (df = 3,28; $F = 4.73$; $p < 0.01$). Posthoc comparisons showed that subjects slept significantly ($p < 0.05$) more following 0 hours of TIB when compared to the subjects in the 4-, 6- and 8-hour TIB conditions. There were no statistically significant differences between the 4-, 6- and 8-hour TIB conditions. A main effect of block was also

TABLE 2. *Mean (standard deviation) of total sleep time for each 4-hour block of the 24-hour enforced bedtime period following 8, 6, 4 and 0 hours time in bed (TIB)*

TIB	1 (0800–1159)	2 (1200–1559)	3 (1600–1959)	4 (2000–2359)	5 (2400–0359)	6 (0400–0759)	Total
8 hours	180 (36)	119 (35)	65 (52)	67 (85)	125 (68)	182 (56)	738 (168)
6 hours	206 (47)	147 (21)	73 (71)	86 (38)	132 (81)	187 (38)	832 (104)
4 hours	224 (18)	131 (80)	66 (84)	59 (65)	172 (60)	182 (60)	834 (137)
0 hours	228 (16)	212 (18)	104 (58)	103 (75)	174 (75)	192 (41)	1013 (177)[a]
x̄ Block	210 (36)	152 (57)[b]	81 (65)[b,c]	79 (67)[b,c]	151 (72)[b,d]	186 (47)[c,d,e]	

[a] Posthoc comparisons of significant main effect of TIB ($p < 0.05$): vs. 8, 6, and 4 hours TIB.
[b] Posthoc comparisons of significant main effect of block ($p < 0.05$): block 1 ≠ blocks 2, 3, 4, 5.
[c] Posthoc comparisons of significant main effect of block ($p < 0.05$): block 2 ≠ blocks 3, 4, 6.
[d] Posthoc comparisons of significant main effect of block ($p < 0.05$): blocks 3, 4 ≠ blocks 5, 6.
[e] Posthoc comparisons of significant main effect of block ($p < 0.05$): block 5 ≠ block 6.

shown (df = 5,140; $F = 29.46$; $p < 0.01$). Posthoc comparisons showed that subjects slept significantly more in block 1 when compared to blocks 2, 3, 4 and 5. Blocks 1 and 6 were comparable. Also, subjects slept more in block 2 when compared to blocks 3 and 4 but less when compared to block 6. The amount of sleep during blocks 3 and 4 was comparable and significantly less when compared to blocks 5 and 6. Finally, the amount of sleep in block 5 was significantly less than that of block 6. There was no significant interaction of TIB by block (df = 15,140; $F = 0.69$; ns).

Recovery sleep architecture

The sleep staging during the 24 hours of the recovery period, following the various TIBs, was also analyzed (Table 3). However, since not all sleep stages were present in each hour block, the data was submitted to a one-factor (TIB condition) MANOVA for total minutes of each stage of sleep during the 24-hour enforced bedtime. There was a main effect of minutes spent in stage 2 NREM sleep (df = 3,28; $F = 3.68$; $p < 0.05$). Posthoc comparisons showed that the total number of minutes spent in stage 2 was significantly lower following the 8-hour TIB when compared to the 0-hours TIB. The other two conditions were intermediate and not significantly different from the 8- or 0-hour TIBs. The main effect for stage 3/4 was also significant (df = 3,28; $F = 12.81$; $p < 0.01$). The posthoc comparisons showed that significantly more stage 3/4 NREM sleep was recorded following 0-hours TIB when compared to the remaining three conditions. Finally, the main effect for stage REM was also significant (df = 3,28; $F = 3.08$; $p < 0.05$). The posthoc comparisons showed that significantly more stage REM was recorded following 0-hours TIB when compared to the 8-hour TIB condition. The 6- and 4-hour TIBs were intermediate and not significantly different. No significant effect for the total number of minutes of stage 1 NREM sleep was found.

As a result of the prolonged recovery period and increased TSTs, the increase in the number of minutes of stage 2 and stage REM is not entirely surprising. Thus, the sleep staging data were next analyzed as percentages of TST. The percentage of each sleep stage was submitted to a one-factor (sleep deprivation condition) MANOVA. The results only showed a main effect for stage 3/4 NREM sleep percent (df = 3,28; $F = 5.11$; $p < 0.01$). The posthoc comparisons showed a higher percentage of stage 3/4 NREM sleep after 0-hours TIB (14 ± 4) when compared to the 4-, 6- and 8-hours TIB (6 ± 5, 8 ± 5 and 6 ± 5, respectively). No differences were found in the 4-, 6- and 8-hour TIB groups.

Pattern of response to the TIB conditions

To statistically characterize the function of the response of the MSLT, TST and sleep stages that showed a main effect of TIB, trend analyses were utilized. The polynomial regression on mean daily sleep latency showed a significantly linear component (df = 1,30; $F = 45.94$; $p < 0.01$) with no quadratic or cubic components evident in the decrease in latency with decreasing TIB. The polynomial regression on total sleep time during the 24-hour enforced bedtime showed a linear component (df = 1,30; $F = 12.29$; $p < 0.01$) and once again no quadratic or cubic components were evident (Fig. 1). The Pearson moment correlation between the mean daily sleep latency and total sleep time during the 24-hour enforced bedtime was −0.39 ($p < 0.05$).

Finally, trend analyses were done to characterize the effects of the TIB on the total number of minutes spent in the various stages of sleep during the 24-hour enforced bedtime. Significant linear components were shown for stage 2 (df = 1,30; $F = 10.75$; $p < 0.01$), stage 3/4 ($F = 25.04$; $p < 0.01$) and stage REM ($F = 8.43$; $p < 0.01$). In addition, there were quadratic and cubic components only for stage 3/4 NREM sleep (F

TABLE 3. *Mean (standard deviation) of sleep stages (minutes and percentages) and trend analyses (for minutes in each stage of sleep) during the 24-hour enforced bedtime period following 8, 6, 4 and 0 hours time in bed (TIB)*

Sleep	TIB	Percent	Minutes	Trend
Stage 1	0	12 (6)	131 (71)	
	4	17 (4)	144 (32)	
	6	18 (7)	147 (53)	
	8	23 (12)	180 (120)	
Stage 2[a]	0	53 (5)	529 (86)[c]	
	4	56 (6)	473 (106)	Linear ($p < 0.01$)
	6	54 (4)	450 (69)	Quadratic (ns)[e]
	8	53 (8)	388 (79)	Cubic (ns)
Stage 3/4[a,b]	0	14 (4)[d]	139 (38)[d]	
	4	6 (5)	49 (31)	Linear ($p < 0.01$)
	6	8 (5)	65 (39)	Quadratic ($p < 0.03$)
	8	6 (5)	40 (33)	Cubic ($p < 0.03$)
Stage REM[a]	0	21 (4)	213 (76)[c]	
	4	20 (3)	171 (45)	Linear ($p < 0.01$)
	6	20 (3)	169 (38)	Quadratic (ns)
	8	18 (5)	132 (48)	Cubic (ns)

[a] Significant main effect of minutes ($p < 0.05$).
[b] Significant main effect of percent ($p < 0.05$).
[c] Posthoc comparisons ($p < 0.05$): vs. 8 hours TIB.
[d] Posthoc comparisons ($p < 0.05$): vs. 8, 6, 4 hours TIB.
[e] ns = not significant.

= 6.62 and $F = 6.77$, respectively; $p < 0.05$). As for the percent of stage 3/4 NREM sleep, a linear component was demonstrated (df = 1,30; $F = 8.54$; $p < 0.01$) but no quadratic component was shown.

DISCUSSION

The results of this experiment document that the degree of daytime sleepiness is directly related to the amount of sleep on the previous night. The curtailment of the time spent in bed (for all practical purposes the loss of sleep), by as little as 2 hours, was followed by a statistically significant increment in the level of sleepiness. Increasing restriction of TIB resulted in linear increments in daytime sleepiness levels with the loss of one night sleep (0-hours TIB condition) producing maximal levels of sleepiness.

The response of the TIB conditions was also demonstrated on the amount of sleep accumulated during the 24-hour enforced bedtime. As expected, the loss of one night of sleep was followed by a significant increase in recovery sleep which exceeded the 10–20% of recovery sleep previously documented (using ad libitum or slightly extended bedtime methodologies) in sleep deprivation studies (11,12). The 24-hour enforced bedtime effectively removed the behavioral controls that are routinely imposed on sleep and that have previously been described (17). No significant differences were documented for those subjects in the 4-, 6- and 8-hour TIBs, although they showed a clear linear response to the TIB conditions on total sleep

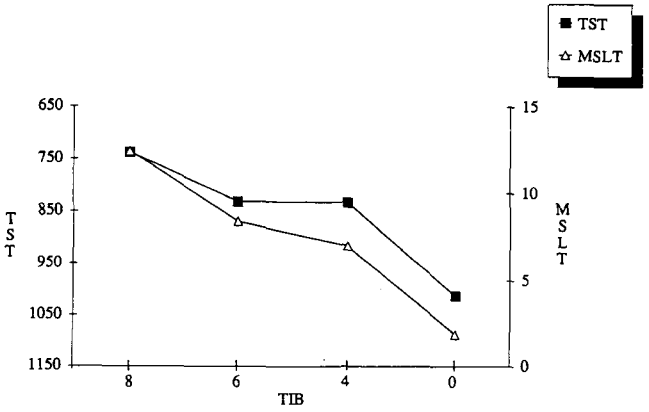

FIG. 1. Total sleep times (minutes) and mean MSLTs following 8, 6, 4 and 0 hours time in bed (TIB).

time (during the enforced bedtime). In part, this is due to the variability in total sleep times. It is unlikely that the variability is idiosyncratic to the participants of this study because a similar finding was described by Aserinsky (13) some 23 years ago. In an experiment to determine the maximal capacity for sleep within a 30-hour period, he noted a range from 14.86–27.37 hours. It is important to note that the methodology he utilized during the enforced bedtime period was similar to the one utilized in the present experiment. Furthermore, the total sleep time during the last 24-hour period in Aserinsky's study was 13.10 hours, which is comparable to the 12.3 hours derived following the 8-hour TIB condition in the present study. In a previous study (15) using the 24-hour enforced bedtime methodology, a mean total sleep time of 10.8 hours (over the 24-hour period) following an 8-hour TIB was reported. In that study, subjects were given a 10-hour TIB the night before entering the experiment, which is in contrast with the methodology utilized in the present experiment. Although it is difficult to argue for chronic sleep deprivation in face of a mean MSLT of 12.3 minutes, it is possible that a homeostatic sleep response is present in these subjects while they are still able to maintain alert levels on the MSLT.

The complexity of the results of the 24-hour enforced bedtime is further highlighted by the results of the time spent in the various sleep stages. Clearly the pattern of response was different for stage 2 NREM and REM sleep from that documented for stage 3/4 NREM sleep. These results show that the recovery of minutes spent in stage 2 NREM and REM sleep parallel the recovery of TST in the 24-hour enforced bedtime, whereas stage 3/4 NREM sleep did not. These results emphasize the importance of the methods used (ad libitum sleep, slightly extended bedtime or enforced bedtime) when estimating the amount of recovery of the different sleep stages. Using ad libitum or slightly extended bedtimes (with standard EEG technology), previous studies had

suggested that slow wave sleep is the central component in sleep termination. Similar results have been derived in studies using EEG power spectra (18). In this study, using a 24-hour enforced bedtime methodology, the results indicate that although the percentage of stage 3/4 NREM sleep shows a linear response to sleep loss, the amount of sleep per se is also an important contributor to sleep drive.

The pattern of sleep during the 24-hour enforced bedtime showed that the recovery continued beyond the first 8 hours of the recording. However, a significant circadian rhythm effect was observed in blocks 3 and 4 across the four TIBs where subjects slept very little. The amount of sleep increased during blocks 5 and 6 as the circadian effects ceased to interfere with sleep. Despite this improvement, the amount of sleep remained low. Although the circadian effects are consistent with previous reports in the literature (17), it is possible that the absence of a TIB by time interaction is the result of the enforced bedtime methodology (i.e. having subjects in bed for such a prolonged period). However, other possible hypotheses need to be entertained as well. For example, it is possible that only a finite amount of sleep can be recovered in a 24-hour period. Although entirely speculative at present, this hypothesis is particularly relevant to the pathophysiology of the insufficient sleep syndrome (19). It has been suggested that patients affected with this condition maintain sleep schedules that are insufficient relative to their sleep need. As a result, sleep loss is believed to be the primary causal etiology of daytime sleepiness in this group of patients. Thus, it would be of interest to document the outcome of a 24-hour enforced bedtime protocol in a sample of patients with this diagnosis. These patients would be expected to experience a significant improvement in their daytime sleepiness levels. However, consistent with the above hypothesis, the degree of improvement would hinge on the amount and chronicity of sleep loss.

Most important, the results of this study demonstrate that both the propensity to fall asleep and the propensity to stay asleep show linear responses to the prior TIB conditions. Whereas evidence for a systematic response can be inferred from a variety of studies where MSLTs have been done following various TIB conditions (20), this study systematically measured both level of sleepiness and total sleep time during a 24-hour enforced bedtime. The fact that both measurements disclosed a systematic pattern of response to the experimental manipulation gives credence to the concept of homeostatic balance in sleep/wake function. Although it is true that individuals differ in the amount of sleep they require, the data suggest that variations in the amount devoted to sleep will show systematic effects on the following day's propensity to fall asleep and in the amount of sleep a subject would accrue when social and behavioral controls are removed.

Finally, it is clear from the present results that more research is required to gain further understanding about the determinants of sleep time. The incomplete recovery of lost sleep remains unexplained and is both of practical and theoretical importance. In contrast with the hypothesis of limited sleep recovery (in a 24-hour period), the concept of core and optional sleep has been previously suggested (21). The latter hypothesis would predict that less than half of lost sleep needs to be recovered. However, the 24-hour enforced bedtime has documented a greater amount of sleep recovery (15). It is likely that, in addition to social, behavioral and circadian controls on sleep/wake function, there are yet unknown factors that determine sleep time.

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