

ACUTE RESTRICTION OF NOCTURNAL SLEEP IN CHILDREN¹

MARY A. CARSKADON, KIM HARVEY, AND WILLIAM C. DEMENT

*Stanford University School of Medicine*²

Summary.—Sleep, performance, and sleepiness were evaluated in nine (6 girls, 3 boys) children (ages 11 to 13.2 yr.) with a view toward determining whether children are more sensitive to sleep restriction than adults. In this 3-day study (immediately preceded by 3 adaptive days), sleep was permitted for 10 hr. on the baseline and recovery night, and for 4 hr. on a single restricted night. Effects of sleep restriction and subsequent recovery on nocturnal sleep parameters were very comparable to results seen in adult subjects. No significant effects of the procedure were seen in performance on abbreviated versions of the Wilkinson Addition Test and Williams Word Memory Test or on a listening attention task. Multiple sleep latency tests showed a significant increase with daytime sleepiness following sleep restriction, which persisted into the morning following recovery sleep. Children appear to be able to tolerate a single night of restricted sleep, although they do not recover as rapidly as adult subjects.

The present study examines the effects of a single night's reduced sleep on the sleep, performance, and daytime sleepiness in children, with a view toward determining whether children are more sensitive to such a procedure than adults.

Many studies have examined the effects of nocturnal sleep restriction in adults, usually young adult college students. These studies have assessed various sleep restriction regimens, ranging from one or two acutely restricted nights to weeks or months of gradual nocturnal sleep reduction. Regardless of the specific schedule, the studies have shown similar effects of sleep restriction on nocturnal sleep patterns when sleep is reduced to 4 hr. or greater. In general, all sleep stages except Stages 3 and 4 are significantly curtailed by sleep restriction (Carskadon & Dement, in press; Johnson & MacLeod, 1973; Mullaney, *et al.*, 1977; Taub and Berger, 1976; Webb & Agnew, 1974, 1975). Latencies to sleep onset, Stage 4 sleep, and REM sleep are reduced (Carskadon & Dement, in press; Johnson & MacLeod, 1973; Mullaney, *et al.*, 1977; Webb & Agnew, 1975). Wakefulness within the sleep period also declines during sleep restriction (Carskadon & Dement, in press; Johnson & MacLeod, 1973; Mullaney, *et al.*, 1977; Webb & Agnew, 1975).

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²Request reprints from M. A. Carskadon, Sleep Research Center, Department of Psychiatry and Behavioral Sciences, Stanford University School of Medicine, Stanford, California 94305.

Recovery sleep following sleep restriction differs depending upon the type of recovery schedule that is given. When the recovery schedule is similar to the baseline schedule (Carskadon & Dement, in press; Dement & Greenberg, 1966), Stage 1 sleep and wakefulness tend to remain below the basal level, and Stages 3, 4, and REM tend to rise above the baseline. With an *ad libitum* recovery sleep period (Webb & Agnew, 1975), Stages 1 and 2 sleep tend to be greater than baseline; Stages 3, 4, and REM, along with wakefulness, tend to achieve the basal value; while latency to sleep onset remains below the baseline level.

Several experiments have also examined subjects' abilities to perform tasks during a period of restricted nocturnal sleep. One gradual sleep reduction study found that "Performance . . . was not impaired during sleep reduction" (Friedmann, *et al.*, 1977, p. 248). In a similar study of Johnson and MacLeod (1973), performance decrements began to appear as sleep was reduced to 5.5 hr. or fewer. Webb and Agnew (1974), whose subjects maintained a 5.5-hr. sleep schedule for 60 days, found a slight gradual decline in performance on certain tasks and no change in performance on others. These authors attributed performance decrements to a declining willingness of their subjects to perform. Wilkinson (1968) evaluated subjects during a number of acute sleep-restriction schedules and found no performance decrement after a single night's sleep restriction until sleep was reduced to 2 hr. or fewer. With two consecutive restricted nights, Wilkinson (1968) found that performance was impaired if 5 hr. of sleep or fewer were permitted.

Daytime sleepiness has been examined in two sleep-restriction studies, one using the Stanford Sleepiness Scale (Friedmann, *et al.*, 1977), and one using the scale in combination with an analog self-rating sleepiness scale and the Multiple Sleep Latency Test (Carskadon & Dement, in press). In the Carskadon and Dement (in press) study, the sleep latency test showed a cumulative daytime sleepiness over seven days of reduced (5 hr.) sleep, while subjective rating scales reached a plateau after four days.

METHOD

Subjects

Nine children who have participated in the Stanford Summer Sleep Camp program (Carskadon, *et al.*, 1980) agreed to take part in the experiment. The subjects included six girls whose ages ranged from 11.4 to 13 yr. ($M = 12.5$) and three boys, ages 11, 11.3, and 13.2. All children were in excellent health and had no personal or family history of sleep disorders. Informed consent was obtained from each child and parent.

Procedure

The children stayed at the Stanford Summer Sleep Camp in groups of

three or four for six consecutive days, of which the first three were the yearly three-day assessments, and the last three were the experimental period. The experimental period consisted of one baseline (BSLN) day, identical in every respect to the three previous days, one day on which nocturnal sleep was restricted (SR), and one recovery (REC) day, identical to the baseline. Bedtime on baseline and recovery days was 2200, and subjects were awakened at 0800. The restricted sleep bedtime was 0400, with an 0800 rising time.

All sleep periods were recorded in individual bedrooms. Electrodes were applied to record electroencephalogram (EEG) from C3 and C4 (Jasper, 1958), electro-oculogram (EOG) from left and right outer canthi, and electromyogram (EMG) from on and beneath (mental/submental) the chin (Rechtschaffen & Kales, 1968). Additional EEG electrodes were placed over occipital regions (O1 or O2) to assist in determinations of sleep onset in subjects with poorly visualized central alpha rhythm. EEG was recorded referentially on Grass Model 7 polygraphs at a paper speed of 10 mm/sec. with high frequency cut-off at 35 Hz and a low frequency filter setting of 1.0 Hz, calibrated at 50 μ V/cm. Sleep stages were scored in 30-sec. epochs according to standard criteria (Rechtschaffen & Kales, 1968).

A schedule of daytime testing was enforced each day. Three 1-hr. performance test batteries were given daily at 1000, 1400, and 2000. A fourth test battery was added at 0200 on the restricted sleep night. Each battery consisted of three tests. Throughout the performance tests, subjects were seated at desks in their individual bedrooms, which were curtained from view of other rooms. Details of the testing procedures are described in Carskadon (1979) and Carskadon, *et al.* (in press); a summary is presented below.

An abridged 30-min. form of the Wilkinson Addition Test was given as the first test in each battery. In adults, this test has been shown to measure performance decrements associated with sleep restriction or sleep deprivation (Wilkinson, 1968). This test requires subjects to add columns of five two-digit numbers. Results were obtained for the number of problems attempted and the number of correct additions.

A shortened form of the Williams Word Memory Test was given after a brief rest period. This test has also shown measurable changes in adults undergoing sleep loss (Williams, *et al.*, 1966). Each test contained a list of 25 four-letter words selected in a semi-random fashion so that no word was repeated on any test. The list was read and spelled, and the child was given 5 min. to "write down in any order as many of the words as you remember from the list" on a blank sheet of paper. The test score was derived as the number of words correctly recalled.

The final test in each battery was a listening attention task specifically prepared to assess vigilance in children. The listening task comprised 10-min.

passages edited from a series of children's books (Evans-Pritchard, 1972) and containing 70 key words. The word "because" appeared 20 times in each tape and a second key word, chosen to represent the major theme of the passage, appeared 50 times. When the taped passage was played over a loud speaker, the child was instructed to press one of two switches (attached to his desk) when he heard "because" and the other when he heard the second key word. The listening attention test was scored for the total number of key word signals missed on each tape.

Daytime sleepiness was assessed using the multiple sleep latency test, given six times a day at 2-hr. intervals beginning at 0930 each morning. Three sleep latency measures were added during sleep restriction at 2130, 2330, and 0130. Vigorous activity was suspended 15 min. before each test. EEG and EOG were monitored continuously during the sleep latency tests. Five min. before the tests, subjects were asked to lie in bed and perform several maneuvers (open eyes, close eyes, etc.) to ensure that an adequate signal was obtained. At the beginning of each test, subjects were requested to "lie quietly, keep your eyes closed, and try to fall asleep." The tests began when the lights were extinguished and bedroom doors closed. Each sleep latency test lasted until three consecutive 30-sec. epochs of sleep or 20 min. if no sleep occurred.

Meals were given at 0815, 1200, and 1800. Caffeinated beverages were forbidden throughout the study. Each subject was accompanied and observed by a technician between tests. Recreational activities included volleyball games for about 30 min. after lunch and supper and bowling for about 45 min. at 1600. Shorter breaks were spent playing more sedentary games or watching television. During the late night hours of the restricted-sleep night, subjects were treated to a feature-length movie, interrupted as necessary to accommodate testing procedures. No physical or mental coercion was used to maintain wakefulness. All children appeared to enjoy the opportunity to stay up late, and no difficulties were encountered in keeping them awake.

RESULTS

Data from the three experimental days were analyzed using repeated-measures analysis of variance for tests given each of the three days. Significant differences among mean values were evaluated using the Newman-Keuls test. A .05 rejection region was used throughout.

Nocturnal Sleep

Table 1 lists the mean values for selected sleep parameters. Stages 1, 2, and 3, and REM sleep were reduced significantly below the baseline value when sleeping time was restricted. Stage 4 sleep, on the other hand, did not vary significantly from baseline during sleep restriction. Sleep onset latency

TABLE 1
NOCTURNAL SLEEP: VALUES IN MINUTES

Measures		Baseline	Sleep Restriction	Recovery	F	p																																																																																																
Total Sleep Time**	M	562	235	583	236.41	<.01																																																																																																
	σ	22	2	8			Stage 1*	M	52	15	40	26.48	<.01	σ	16	6	10	Stage 2†	M	236	68	254	142.32	<.01	σ	17	22	35	Stage 3†	M	40	18	40	17.04	<.01	σ	13	9	13	Stage 4	M	101	95	109	1.73		σ	10	12	27	REM†	M	133	45	145	80.48	<.01	σ	17	25	13	Wake After Sleep Onset	M	6	0	3	1.53		σ	10	0	3	Sleep Onset Latency*	M	20	3	11	20.35	<.01	σ	11	2	6	REM Latency	M	86	67	91	1.83		σ	36	14	39	Stage 4 Latency*	M	34	17	26	17.43	<.01	σ
Stage 1*	M	52	15	40	26.48	<.01																																																																																																
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Note.—Newman-Keuls test of significant differences:

**Baseline and Recovery > Sleep Restriction ($p < .01$); Recovery > Baseline ($p < .01$).

*Baseline and Recovery > Sleep Restriction ($p < .01$); Baseline > Recovery ($p < .05$).

†Baseline and Recovery > Sleep Restriction ($p < .01$); Baseline = Recovery.

and latency from sleep onset to Stage 4 sleep declined on the restricted-sleep night, while latency from sleep onset to REM sleep was not significantly altered by the procedure. Although the statistical procedure did not identify a significant change in wakefulness after sleep onset, it is notable that none of the children experienced any arousals on the restricted-sleep night.

On the recovery night, total sleep time was greater than on baseline in every subject. Stage 1 sleep remained below the baseline value, while Stages 2, 3, 4, and REM sleep achieved basal or slightly (though not significantly) higher values. Sleep onset latency and Stage 4 latency remained below baseline levels on the recovery night.

Performance Tests

The performance tests demonstrated no significant effects of restricted sleep or recovery. As shown in Table 2, the performance test scores were highly variable and no consistent trends were evident. One child, with poor arithmetic skills, was unable to perform the addition task properly and her data were not included in the analysis of this test. There appeared to be a tendency for children to perform most poorly on the arithmetic and listening

TABLE 2
PERFORMANCE TESTS

Test	Battery		Baseline	Sleep Restriction	Recovery
Wilkinson Addition Test: Number Attempted†					
	1000	<i>M</i>	71.0	71.6	68.5
		<i>σ</i>	16.5	16.5	13.3
	1400	<i>M</i>	67.5	68.2	71.8
		<i>σ</i>	16.6	15.7	17.8
	2000	<i>M</i>	76.2	70.9	79.9
		<i>σ</i>	14.9	11.6	17.7
	0200*	<i>M</i>	73.6		
		<i>σ</i>	14.5		
Wilkinson Addition Test: Number Correct†					
	1000	<i>M</i>	58.5	59.8	54.6
		<i>σ</i>	16.0	22.7	15.0
	1400	<i>M</i>	54.4	54.4	56.4
		<i>σ</i>	17.4	17.7	20.6
	2000	<i>M</i>	62.8	55.0	61.6
		<i>σ</i>	14.7	14.4	18.6
	0200*	<i>M</i>	57.6		
		<i>σ</i>	21.8		
Williams Word Memory: Number Recalled					
	1000	<i>M</i>	8.7	6.7	8.9
		<i>σ</i>	4.2	4.2	5.3
	1400	<i>M</i>	7.2	7.2	7.8
		<i>σ</i>	5.8	4.3	4.6
	2000	<i>M</i>	6.7	8.3	9.2
		<i>σ</i>	3.5	6.1	5.3
	0200*	<i>M</i>	7.7		
		<i>σ</i>	3.8		
Listening Attention Task: Number Missed					
	1000	<i>M</i>	13.9	14.6	13.8
		<i>σ</i>	8.1	8.6	7.8
	1400	<i>M</i>	19.7	16.8	11.9
		<i>σ</i>	7.8	10.7	9.1
	1000	<i>M</i>	11.7	11.3	14.2
		<i>σ</i>	7.1	8.5	12.8
	0200*	<i>M</i>	15.6		
		<i>σ</i>	9.9		

†One subject did not complete the Addition test properly.

*The 0200 Battery was not included in the analysis. Data are listed in the Baseline column because the 0200 Battery was given on the late night that followed the baseline day and preceded the sleep restriction day.

tests given in the 1400 testing batteries on baseline and restricted-sleep periods; however, this effect was not statistically significant when the data were analyzed for time-of-day effects.

Multiple Sleep Latency Tests

Table 3 lists the over-all daily mean sleep latencies and the values for

TABLE 3
MULTIPLE SLEEP LATENCY TEST: VALUES IN MINUTES

Time		Baseline	Sleep Restriction	Recovery	F	p
Daily Mean**	M	16.8	9.5	13.6	15.09	.01
	σ	3.3	4.3	4.5		
0930*	M	17.2	6.4	7.8	15.55	.01
	σ	4.9	3.8	7.3		
1130†	M	17.4	10.3	14.1	5.46	.05
	σ	4.3	6.7	7.2		
1330	M	15.2	9.6	12.9	3.54	
	σ	5.5	6.3	6.7		
1530‡	M	16.5	8.0	13.6	8.83	.01
	σ	6.2	5.3	6.9		
1730	M	15.4	10.6	16.6	2.87	
	σ	7.1	6.4	5.4		
1930‡	M	19.3	12.0	16.8	9.00	.01
	σ	1.4	5.5	4.5		

Note.—Newman-Keuls test of significant differences:

†Baseline > Sleep Restriction ($p < .05$); Recovery = Baseline and Sleep Restriction.

‡Baseline > Sleep Restriction ($p < .01$); Recovery > Sleep Restriction ($p < .01$); Recovery = Baseline.

*Baseline > Sleep Restriction ($p < .01$); Baseline > Recovery ($p < .01$); Recovery = Sleep Restriction.

**Baseline and Recovery > Sleep Restrictions ($p < .01$); Baseline > Recovery ($p < .05$).

each time of day the test was given. The daily mean scores were significantly lower than baseline on the restricted-sleep and recovery days. When time of day was examined, no significant alterations were found for either the 1330 or 1730 testing sessions. On each of the other four daily tests, however, the restricted-sleep scores were significantly reduced from baseline.

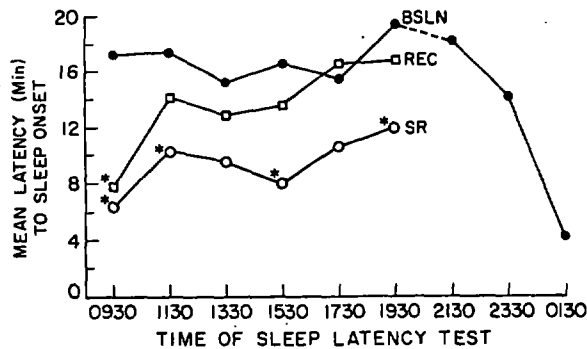


FIG. 1. Mean sleep latency test scores for tests given on Baseline (darkened circles), Sleep Restriction (open circles), and Recovery (open squares) days. The tests indicated at 2130, 2330, and 0130 were given on the night that subjects stayed awake until 0400, immediately after Baseline day and before the Sleep Restriction day. Asterisks indicate those tests on which scores were significantly lower than Baseline.

Although the daily mean sleep latency scores suggested that recovery values were below baseline, the time-of-day analysis showed that only at 0930 were the sleep latencies significantly below baseline. Fig. 1 also illustrates an abrupt decline of sleep latency scores at the 0130 test on the night when the children stayed up late. The lowest mean sleep latency was seen on this test.

DISCUSSION

The basal nocturnal sleep data include certain differences from the norms of Williams, *et al.* (1974). These differences, as described elsewhere for the larger group of Sleep Camp subjects (Carskadon, *et al.*, 1980; Carskadon, *in press*), are probably due chiefly to differences in recording time, scoring epoch length, and recording parameters. The findings on nocturnal sleep during the restricted sleep were largely comparable to those reported for sleep restriction in adults (Carskadon & Dement, *in press*; Dement & Greenberg, 1966; Johnson & MacLeod, 1973; Mullaney, *et al.*, 1977; Taub & Berger, 1976; Webb & Agnew, 1974, 1975). With a few minor exceptions, the changes were in the expected directions. Thus, although REM latency during restricted sleep was not significantly reduced, the trend was in the appropriate direction. In addition, the children did not show a recovery rebound of Stages 3, 4, and REM as had been reported by others for adult subjects (Carskadon & Dement, *in press*; Dement & Greenberg, 1966). Had a second or third night of recovery sleep been given, such changes might have become apparent.

The negative performance test findings emphasize the difficulty of showing performance decrements with moderate sleep loss. Although each of the tests used in this study have shown significant impairment with total sleep loss in adults (Carskadon & Dement, 1979) and children (Carskadon, 1979), none were sufficiently sensitive to measure decrements following sleep restriction. One factor that may have affected this lack of sensitivity appears to be the relative brevity of the tests—the longest was only 30 min. Kleitman (1963) and Wilkinson (1968) have emphasized that task duration is a major factor determining a test's sensitivity to sleep loss effects. Although we felt that the abridged tasks might have been more sensitive for children, apparently the young subjects are able to deal with short tests on a par with adults.

The Multiple Sleep Latency Test was unique in suggesting that children were more severely affected by sleep restriction than adults. Sleep latencies showed a marked reduction after a reduced night of sleep in the children. Furthermore, recovery of latency scores was not fully established after the 10-hr. recovery night. Although we do not have data from older subjects that are strictly comparable to this study, we have examined sleep latency scores in 10 young adults whose sleep was restricted to 5 hr. on seven consecutive nights (Carskadon & Dement, *in press*). In these older subjects, the

basal sleep latency test scores (following 10 hr. of sleep) were very similar to basal scores in the children; however, a reduction of sleep latency scores comparable to that in the children did not occur until after four nights of restricted sleep. Furthermore, the recovery scores of older subjects after seven consecutive nights of sleep restriction achieved basal values after only one 10-hr. night of sleep. The sleep latency recovery scores in children appeared more similar to those reported in young adults following about 60 hr. without sleep (Carskadon & Dement, 1979) and children kept awake one entire night (Carskadon, *et al.*, in press), in whom a gradual recovery of sleep latency scores occurred following a full night of sleep. In each of these previous studies, the gradual return of sleep latency scores to basal values was attributed to delayed recovery and not to a shift of the sleep-wake cycle. Both studies included a second recovery day on which sleep latencies fully achieved the basal values, suggesting that a phase delay had not occurred.

We suggest that, although children appear to be able to tolerate a single night of sleep restriction without a marked decrement of performance on brief tasks, the extent of daytime sleepiness that occurs is not trivial. With additional nights of short sleep, it is likely that cumulative sleepiness (Carskadon & Dement, in press) might rapidly become a significant problem. Finally, children appear to require more time than adults to recuperate fully from nocturnal sleep restriction. It is not clear at the present time whether the apparent differences represent maturational changes or simply the habituation of older subjects to presumed repeated exposure to sleep restriction.

REFERENCES

- CARSKADON, M. A. Determinants of daytime sleepiness: adolescent development, extended and restricted nocturnal sleep. Unpublished doctoral dissertation, Stanford Univer., 1979.
- CARSKADON, M. A. The second decade. In C. Guilleminault (Ed.), *Disorders of sleeping and waking: indications and techniques*. Palo Alto, CA: Addison-Wesley, in press.
- CARSKADON, M. A., & DEMENT, W. C. Effects of total sleep loss on sleep tendency. *Perceptual and Motor Skills*, 1979, 48, 495-506.
- CARSKADON, M. A., & DEMENT, W. C. Cumulative effects of sleep restriction on daytime sleepiness. *Psychophysiology*, in press.
- CARSKADON, M. A., HARVEY, K., & DEMENT, W. C. Sleep loss in early adolescents. *Sleep*, in press.
- CARSKADON, M. A., HARVEY, K., DUKE, P., ANDERS, T. F., LITT, I. F., & DEMENT, W. C. Pubertal changes in daytime sleepiness. *Sleep*, 1980, 2, 453-460.
- DEMENT, W. C., & GREENBERG, S. Changes in total amount of stage four sleep as a function of partial sleep deprivation. *Electroencephalography and Clinical Neurophysiology*, 1966, 20, 523-526.
- EVANS-PRITCHARD, E. *Peoples of the earth*. Vol. 1-20. Suffern, NY: Danbury Press, 1972.
- FRIEDMANN, J., GLOBUS, G., HUNTLEY, A., MULLANEY, D., NAITOH, P., & JOHNSON, L. C. Performance and mood during and after gradual sleep reduction. *Psychophysiology*, 1977, 14, 245-250.

- JASPER, H. (Committee Chairman). The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology*, 1958, 10, 371-375.
- JOHNSON, L. C., & MACLEOD, W. Sleep and awake behavior during gradual sleep reduction. *Perceptual and Motor Skills*, 1973, 36, 87-97.
- KLEITMAN, N. *Sleep and wakefulness*. Chicago: Univer. of Chicago Press, 1963.
- MULLANEY, D. J., JOHNSON, L. C., NAITOH, P., FRIEDMAN, J. K., & GLOBUS, G. G. Sleep during and after gradual sleep reduction. *Psychophysiology*, 1977, 14, 237-244.
- RECHTSCHAFFEN, A., & KALES, A. (Eds.) *A manual of standardized terminology, techniques and scoring system of sleep stages of human subjects*. Los Angeles: Brain Information Service/Brain Research Institute, University of California at Los Angeles, 1968.
- TAUB, J. M., & BERGER, R. J. The effects of changing the phase and duration of sleep. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, 2, 30-41.
- WEBB, W. B., & AGNEW, H. W., JR. The effects of a chronic limitation of sleep length. *Psychophysiology*, 1974, 11, 265-274.
- WEBB, W. B., & AGNEW, H. W., JR. The effects on subsequent sleep of an acute restriction of sleep length. *Psychophysiology*, 1975, 12, 367-370.
- WILKINSON, R. T. Sleep deprivation: performance tests for partial and selective sleep deprivation. In L. E. Abt & B. F. Riess (Eds.), *Progress in clinical psychology*. Vol. 8. New York: Grune & Stratton, 1968. Pp. 28-43.
- WILLIAMS, H. L., GIESEKING, C. F., & LUBIN, A. Some effects of sleep loss on memory. *Perceptual and Motor Skills*, 1966, 23, 1287-1293.
- WILLIAMS, R. L., KARACAN, I., & HURSCH, C. J. *EEG of human sleep: clinical applications*. New York: Wiley, 1974.

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