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Respiration During Sleep in Children

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In 22 children (11 boys and 11 girls), aged 9 to 13 years, respiration was monitored during one night of sleep. No child had a significant history of breathing problems during sleep. Sleep was recorded using standard techniques (electroencephalography, electrooculography, electromyography), and respiration was measured with nasal thermistors and abdominal or thoracic strain gauges. Respiratory pauses (five seconds or longer) were determined for all sleep stages. Respiratory rate was scored only in the first and last sleep cycles and during ten waking minutes before sleep onset. Respiratory rate was significantly affected by wakefulness or stage of sleep: highest in wakefulness and stage 1, lowest in stage 2 of the last sleep cycle. Regularity of respiratory rate showed a similar effect. Variance of respiratory rate was significantly lower in girls than boys. Respiratory pauses during sleep were seen in every child, ranging from 3 to 40 pauses per night (average, 17.2 for boys and 18.0 for girls). Significantly greater numbers of pauses per minute were seen in stage 1 and rapid eye movement (REM) sleep than in stages 2, 3 and 4. The longest respiratory pause was 25 seconds. The conclusion is made that a small number of respiratory pauses during sleep are normal in children of this age.

THE ACCUMULATION of evidence linking respiratory abnormalities during sleep in infants to the sudden infant death syndrome (SIDS)[1-5] and findings of sleep-related respiratory abnormalities in adults linked to serious cardiovascular dysfunctions[6,7] have generated an increasing interest in the normal control of respiration during sleep. In addition, Guilleminault and co-workers[8,9] recently reported about a series of children who presented with a sleep apnea syndrome that was apparently related to cardiovascular abnormalities and school failure. There is also evidence in infants and adults that males are affected with SIDS or a sleep apnea syndrome in greater numbers than females.[7,10]

Because normative data on respiration during sleep in children are limited,[11] we evaluated this phenomenon in two groups of normal boys and girls to make comparisons between the sexes.

Subjects and Methods

In 22 children standard polysomnographic recording was done for one night; nasal thermistors and abdominal or thoracic mercury-filled capillary

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ABBREVIATIONS USED IN TEXT

REM = rapid eye movement
NREM = nonrapid eye movement
SIDS = sudden infant death syndrome

strain gauges monitored respiration.

The subjects, all in good health and with normal sleeping habits, were 11 girls (aged 9 years 10 months to 13 years 2 months; average age, 12 years one month) and 11 boys (aged 10 years 3 months to 13 years 8 months; average age, 11 years 10 months). A preselected group of seven children (four girls, three boys) had a family history of narcolepsy in one parent. One of these, a girl, had complained of daytime sleepiness; another, a boy, had suffered from nightmares. Although speculation has been raised about genetic transmission patterns of narcolepsy, no firm evidence is available to support or refute this view. We, therefore, have viewed this group as a variant of normal. Laryngoscopic examination of upper airways by one of us (F.B.S.) while the subjects were awake showed no obvious malformation or obstructions in any of the children.

Data Analysis

Sleep records were scored in 30-second epochs according to standard criteria[12] in which stage 1 nonrapid eye movement (NREM) sleep is light drowsy sleep; stage 2 is spindle sleep; stages 3 and 4 are dominated by slow, high amplitude waves; and rapid eye movement (REM) sleep is characterized by low amplitude, mixed frequency electroencephalographic (EEG) patterns, bursts of rapid eye movements and suppression of skeletal muscle tonus.

Respiratory *pauses* were scored during sleep if airflow (measured by nasal thermistors) ceased for five seconds or longer. A pause was considered an *apnea* episode if airflow cessation lasted ten seconds or longer. Periodic breathing was scored if two respiratory pauses occurred within a 20-second interval.[13] Respiratory rate was counted as the number of breaths per minute and scored only during the ten minutes of wakefulness preceding sleep onset (this criterion level was not reached in six children who fell asleep in less than ten minutes), during the entire first sleep cycle (from sleep onset to the end of the first REM period), and during stage 2 and REM sleep in the last full cycle of the night. The last cycle was considered complete if the final epoch of REM sleep occurred at least ten minutes before the end of the recording.

Results

No significant differences in any of the measurements used were detected between those children with a positive family history of narcolepsy and those without. Therefore, the results for both groups were combined.

Sleep

The girls and boys spent comparable amounts of time asleep. The average total sleep time for the girls was 549.5 minutes (range, 505 to 589 minutes); the average total sleep time for the boys was 535.6 minutes (range, 458 to 577 minutes). No significant differences between boys and girls were found in the proportions of the various sleep stages.

Respiratory Rate

Respiratory rate was quite variable. The range was from a high during stage 1 sleep in one child of 21.4 breaths per minute, to a low of 12.2 breaths per minute during the last REM period in one child. Figure 1 illustrates the average difference in respiratory rate for boys and girls as a function of state. A two-factor (sex and state) repeated measures analysis of variance showed a significant effect of state ($F=9.44$; $df=6,6$; $p<.01$) on respiration rate. Respiration rate was highest during wakefulness and stage 1 and lowest during stage 2 sleep of the last cycle of the night. Although the average respiratory rate for boys was somewhat higher than for girls in every state (Figure 1), this effect was not statistically significant.

To determine the relative respiratory regularity, the standard error of the mean respiratory rate for each state in each subject was examined using a two-factor (sex and state) analysis of variance. This analysis showed that the variance for girls was consistently lower than for boys ($F=5.81$; $df=1,20$; $p<.03$). In addition, the variance was highest in wakefulness and stage 1, followed by the last REM period and the first REM period. It was lowest in stages 3 and 4 and slightly higher in the last stage 2 period ($F=6.73$; $df=6,6$; $p\leq.02$).

Respiratory Pauses

The greatest number of respiratory pauses (40) was found in one 11-year-old boy who had no prior history of snoring or respiratory problems. The fewest respiratory pauses (three) occurred in a 13-year-old girl. The average number of respiratory pauses during sleep was similar in girls (18.0±8.5) and boys (17.2±11.4). Figure 2 illustrates the relationship of the number of respiratory pauses to states of sleep. A two-factor (sex and state) analysis of variance was carried out. This analysis showed no effect of sex, but a significant effect of state ($F=25.34$; $df=3,3$; $p<.03$). The greatest number of pauses per minute occurred in stage 1, followed by approximately 50 percent fewer in REM sleep. Stages 2, 3 and 4 sleep had the fewest number of pauses per minute, averaging less than half the number seen in REM sleep.

All respiratory pauses were of the central type[14] in which airflow past the nasal thermistors and respiratory effort measured by the strain gauges ceased simultaneously. Three children had no respiratory pauses in stage 1 sleep; one had none in stage 2; four had no pauses in stages 3 and 4; and two children had none in REM sleep.

Figure 3 shows the average duration of respiratory pauses in each sleep stage. There were no significant differences in respiratory pause duration between boys and girls for any state. The duration of respiratory pauses in REM sleep was significantly shorter ($p<.01$) than in the other states. There was no significant difference in the average duration of respiratory pauses among stage 1, stage 2, and stages 3 and 4 sleep.

It is of interest that approximately 55 percent of the respiratory pauses followed a body movement. Less than three percent of the respiratory pauses preceded and seemed to initiate a body movement. The pauses that occurred before a movement were typically those of longer duration (longer than 15 seconds). Of the respiratory pauses, 42.5 percent were apneas (that is, ten seconds or longer). The longest period of apnea during sleep was 25 seconds.

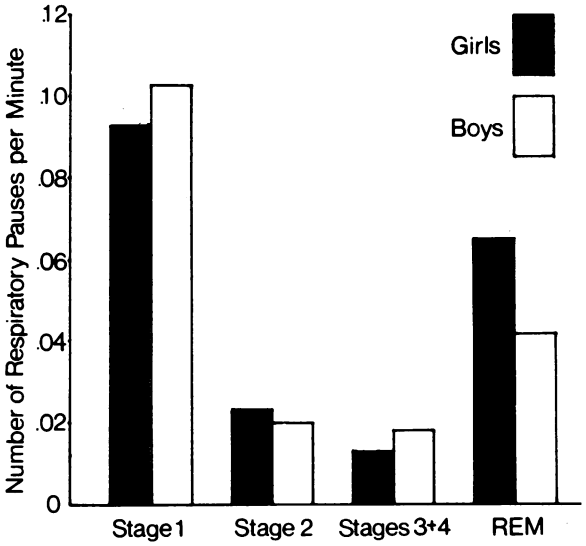

Figure 2.—Average number of respiratory pauses per minute of each sleep state as function of sex.

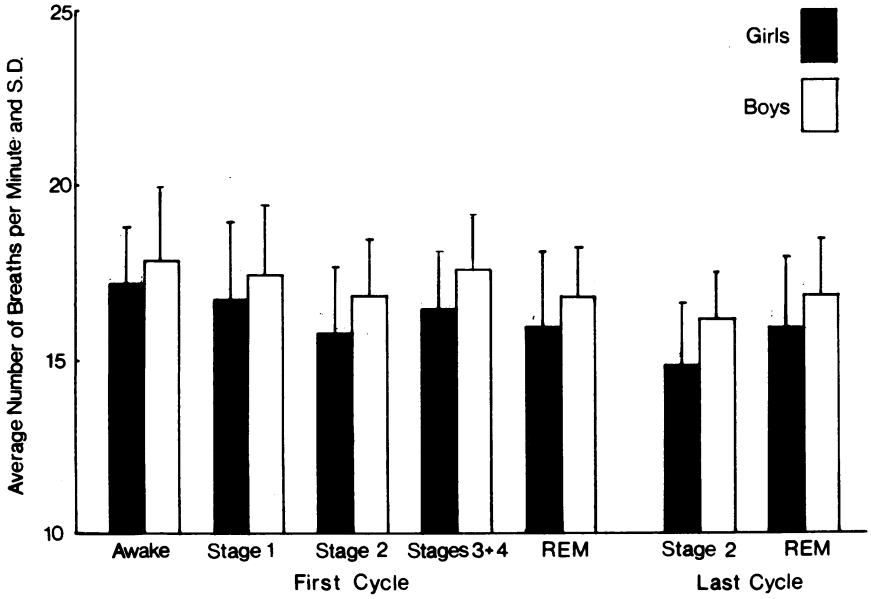

Figure 1.—Mean plus standard deviation of respiratory rate as functions of sex and sleep state.

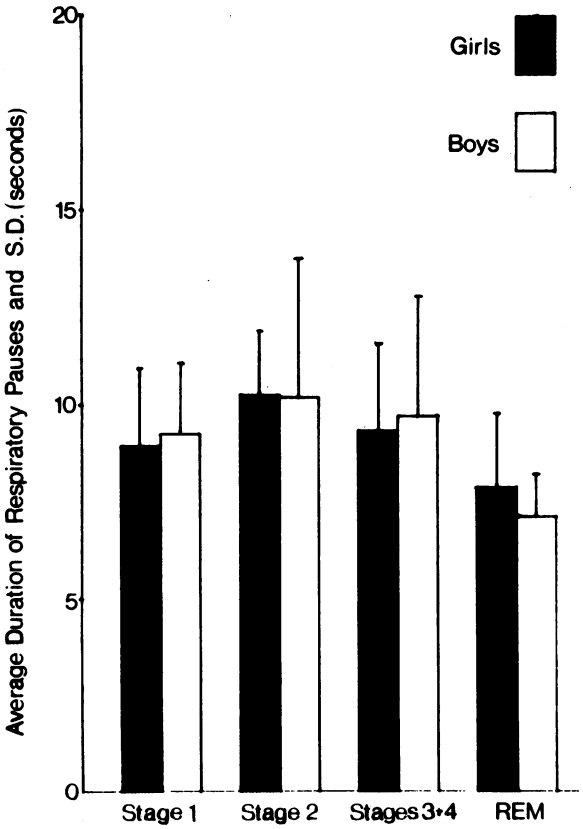

Figure 3.—Average duration plus standard deviation of duration of respiratory pauses in each sleep state as function of sex.

Periodic Breathing

Episodes of periodic breathing were uncommon; seen in only five subjects (three girls and two boys), and three of these occurred on only one occasion in REM sleep. In one boy, three brief periodic breathing episodes were seen: one in stage 4 sleep; one in stage 3 (Figure 4), and one in REM sleep. Similarly, three brief periodic breathing episodes were seen in one girl: once during stage 2 sleep and twice in REM sleep.

Discussion

None of the children had sufficient episodes of apnea to meet the criteria of a sleep apnea syndrome as defined by Guilleminault and co-workers.[7] These criteria require 30 or more *apnea* (ten seconds or longer) episodes in a night of sleep. In addition, none of the children appeared to have episodes of obstructive sleep apnea.[14] Guilhaume and Benoit[11] in their study of normal children reported an average of approximately 50 percent more apneas per child per night than in our subjects.

We conclude that it is normal for sleeping children to have apneas and respiratory pauses, probably of the central type, particularly following body movements and in REM sleep. The distribution of these respiratory pauses across

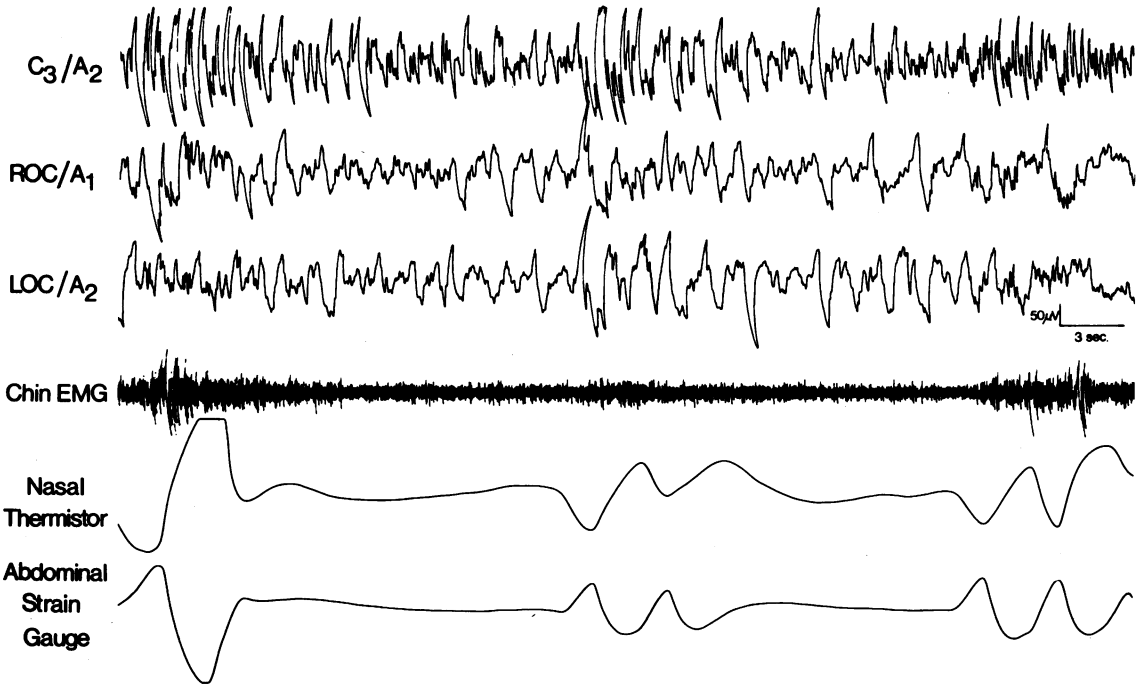

Figure 4.—Polysomnographic recording of a periodic breathing episode during slow wave sleep in an 11-year-old boy.

sleep states was consistent with findings in normal adult subjects, as was the decline in respiratory rate from beginning to end of night.[15] On the other hand, the lack of a rise in respiratory rate during REM sleep was not consistent with most studies in normal subjects.[15] This finding may reflect, however, a time of night effect. That is, while the average REM period respiratory rate in the first sleep cycle was actually lower than the respiration rate in stages 3 and 4 (in 16 subjects), the respiration rate in the last REM period was higher (15 subjects) than that in the immediately preceding stage 2.

The differences in number of apneas between men and women reported by Guilleminault and Dement[16] were not found in the children. The only difference between boys and girls was a more regular respiratory rate in girls than in boys. This finding suggest a male-female difference in the control of respiration during sleep that is not reflected in the number or duration of respiratory pauses. Our inability to show male-female differences in respiratory variables during sleep in children may reflect the prepubertal status of most of the children.

Finally, it is clear from our results that there is a vast difference in respiration during sleep between the normal children and children who have a sleep apnea syndrome.[8,9] The normal children had an average of about 18 respiratory pauses per night, with a maximum of 40 in one child, while the fewest number of apnea episodes seen in a child in whom a sleep apnea syndrome was diagnosed was 78 per night,[8] and the most as high as 816 apneas. The effectiveness of treatment in children with a sleep apnea syndrome can be readily assessed by comparison with the normative data. Guilleminault and co-workers[9] reported that in the children in whom a tracheostomy was done, the number of respiratory pauses during sleep declined to values comparable to those seen in the normal children (that is, five or six apnea episodes per night).

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