

Effect of Snoring and Obstructive Respiratory Events on Sleep Architecture in Adolescents

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Objective: To evaluate the effect of snoring and obstructive respiratory events on the distribution of sleep stages and arousals in a nonselected group of adolescents from the general population.

Design: Cross-sectional study.

Setting: Randomly selected secondary schools in Seville, Spain.

Patients: A general population sample of 43 adolescents (mean [SD] age, 13.6 [1.77] years).

Interventions: A questionnaire for the investigation of sleep-related breathing disorders was administered. Symptoms were evaluated according to a 4-point frequency scale. Snorers answered "sometimes" or "often" to the question about snoring, and nonsnorers answered "never" or "rarely." All subjects underwent standard polysomnography at the sleep laboratory.

Results: Twenty-eight subjects were snorers; 15 were nonsnorers. No statistically significant differences were noted between both groups in the percentages of sleep stages, arousal index, awakenings, or wakefulness during sleep. Snorers showed a significantly higher number of respiratory arousals than nonsnorers (mean [SD], 1.14 [1.5] vs

0.33 [0.6], $P < .05$). However, neither the apnea-hypopnea index (AHI) nor the oxygen desaturation index correlated with the arousal index. Twelve snorers (27.5%) had an AHI of 2 or more; 13 nonsnorers (30.2%) had an AHI of less than 2. Snorers with some obstructive respiratory events had a significantly higher number of awakenings, a lower percentage of stage 4 sleep, and a higher number of respiratory events compared with nonsnorers. However, the total number of arousals and the arousal index were similar for both groups. Wakefulness during sleep tended to be longer in snorers than in nonsnorers although differences were not significant. The percentage of respiratory events that terminated with an arousal was greater in snorers who had an AHI of 2 or more than in nonsnorers who had an AHI of less than 2 (mean [SD], 8.4% [9.5%] vs 4.9% [11.53%], $P < .05$).

Conclusions: These data indicate normal sleep architecture in the adolescents. Although snorers as well as adolescents with some polysomnographic abnormality showed a higher number of respiratory arousals than control subjects, most obstructive events did not terminate with a cortical arousal, which may suggest that adolescents share with younger children this mechanism for preserving sleep architecture.

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ADULTS WITH sleep-related breathing disorders (SRBDs) have arousals from sleep causing sleep fragmentation. The term arousal refers to a rapid desynchronization of cerebral bioelectrical activity with or without an associated increase in muscular and vegetative activity. The number and characteristics of arousals are influenced by some factors, such as the subject's age and the different sleep stages at which arousals occur. Arousals constitute an indicator of sleep quality and, therefore, of sleep fragmentation, both in normal and pathologic conditions.¹

Polysomnographic features of SRBDs in adults are well established. A decrease in the percentages of various sleep stages and rapid eye movement (REM) secondary to sleep fragmentation caused by arousals that occur in response to obstructive respiratory events have been shown to frequently occur. On the other hand, cognitive impairment and excessive daytime sleepiness have been related to the frequency of arousals.^{2,3} Clinical and polysomnographic characteristics of children with SRBDs differ notably from those found in adults, with a lower number of respiratory events and a persistent and partial obstructive pattern of the upper airway accompanied by hypercapnia. In ad-

dition, cortical arousals at the end of the obstructive event are infrequent in the pediatric population and, therefore, sleep architecture is usually preserved.⁴

There is little information regarding SRBDs in adolescents. Normative data on polysomnographic factors in the adolescent age group have been recently reported. These data, however, have been collected from series that used a mixed population sample of children and adolescents⁵ and in which there were restrictive selection criteria,⁶ or in which only cardiorespiratory factors of polysomnography were investigated.⁷

Because, to our knowledge; no systematic studies assessing the influence of some variables related to SRBDs on sleep architecture in the adolescent age group have been performed, the objective of this study was to evaluate the effect of snoring and obstructive respiratory events on the distribution of sleep stages and arousals in a non-selected group of adolescents from the general population.

METHODS

STUDY DESIGN

This study is the second phase of a cross-sectional study carried out by our group in a population of 246 adolescents of both sexes ranging in age from 11 through 19 years, the results of which have recently been reported.⁷ In the first phase of this study we investigated a general population sample of 101 adolescents (mean [SD] age, 13.2 [0.8] years) to determine the frequency, symptoms, and polygraphic features of SRBD. A total of 12 schools were randomly selected using the official directory of public and private secondary schools in Seville, Spain. No inclusion or exclusion criteria based on the absence or presence of previous or underlying diseases were established. The study was approved by the institutional review board (Research Ethics board of Virgen del Rocío University Hospital) and the local educational authorities. Written informed consent was obtained from adolescents who voluntarily agreed to take part and from their parents or legal guardians. In this nonselected group of healthy adolescents, symptoms potentially associated with SRBDs showed a similar frequency to that reported for younger children. Snoring was associated with a higher occurrence of other nocturnal symptoms, a more central pattern of body fat distribution, and a higher respiratory disturbance index compared with nonsnorers. Although polygraphic abnormalities were mild, 2 cases of probable SRBDs were found (prevalence rate, 1.9%).

The study included the administration of a questionnaire for the investigation of SRBD symptoms. The questionnaire has been described in detail elsewhere.⁷ Nocturnal and daytime symptoms suggestive of SRBDs were assessed according to a 4-point frequency scale, from "never" to "rarely" (once a week or less), "sometimes" (twice a week), or "often" (thrice a week or more). For this study, snoring was the only nocturnal symptom suggestive of SRBDs analyzed. Snorers answered sometimes or often on the question about snoring, and nonsnorers answered never or rarely. In the second phase of the study, random samples of 40 of 75 snorers and 20 of 171 nonsnorers were invited for an overnight stay in the sleep laboratory for polysomnography. A final sample of 28 snorers (70%) and 15 nonsnorers (75%) (control group) agreed to participate and underwent full polysomnography.

POLYSOMNOGRAPHY

The polysomnography consisted of continuous polygraphic recordings for a whole night from 10 PM to 7 AM using standardized equipment (Somnostar 4100; SensorMedics Corporation, Yorba Linda, Calif) from surface leads for electroencephalography (C3/A2, C4/A1, O1/A2, and O2/A1 placements), electro-oculography, tibial and submental electromyograms, and electrocardiogram. For respiratory sensors we used nasal and oral signals by thermistors; chest and abdominal effort was measured by 2 belt sensors (piezo-electric gauge; Healthdyne Technologies Inc, Marietta, Ga). Arterial oxygen saturation (SaO₂) was recorded by digital pulse oximetry and body position was monitored by the polysomnographic system. Analysis of recordings obtained by polysomnography was performed by an experienced neurophysiologist (G.B.) who was unaware if polysomnograms belonged to a subject in the snoring group or to a control subject.

Sleep studies were performed according to standards for cardiopulmonary sleep studies in children.⁸ A complete cessation of oronasal flow (thermistor signal) with continued respiratory efforts of 5 seconds or more was defined as apnea. Hypopnea was defined as a discernible reduction of 50% or higher in oronasal flow and reduction in oxygen saturation by at least 4% from baseline. Each 30-second epoch of the recording was scored for sleep stage, breathing, oxygenation, and movement. Sleep data were staged according to the system of Rechtschaffen and Kales.⁹ An arousal was defined according to the American Sleep Disorders Association¹⁰ as a sudden burst of alpha electroencephalographic frequency lasting more than 3 seconds accompanied by concurrent electromyographic activity in REM sleep (**Figure**). Each arousal was examined to decide whether it was associated with a respiratory event. This was determined by checking for the presence of apnea or hypopnea preceding each arousal. Awakenings were defined as arousals lasting for 30 seconds or longer.¹¹

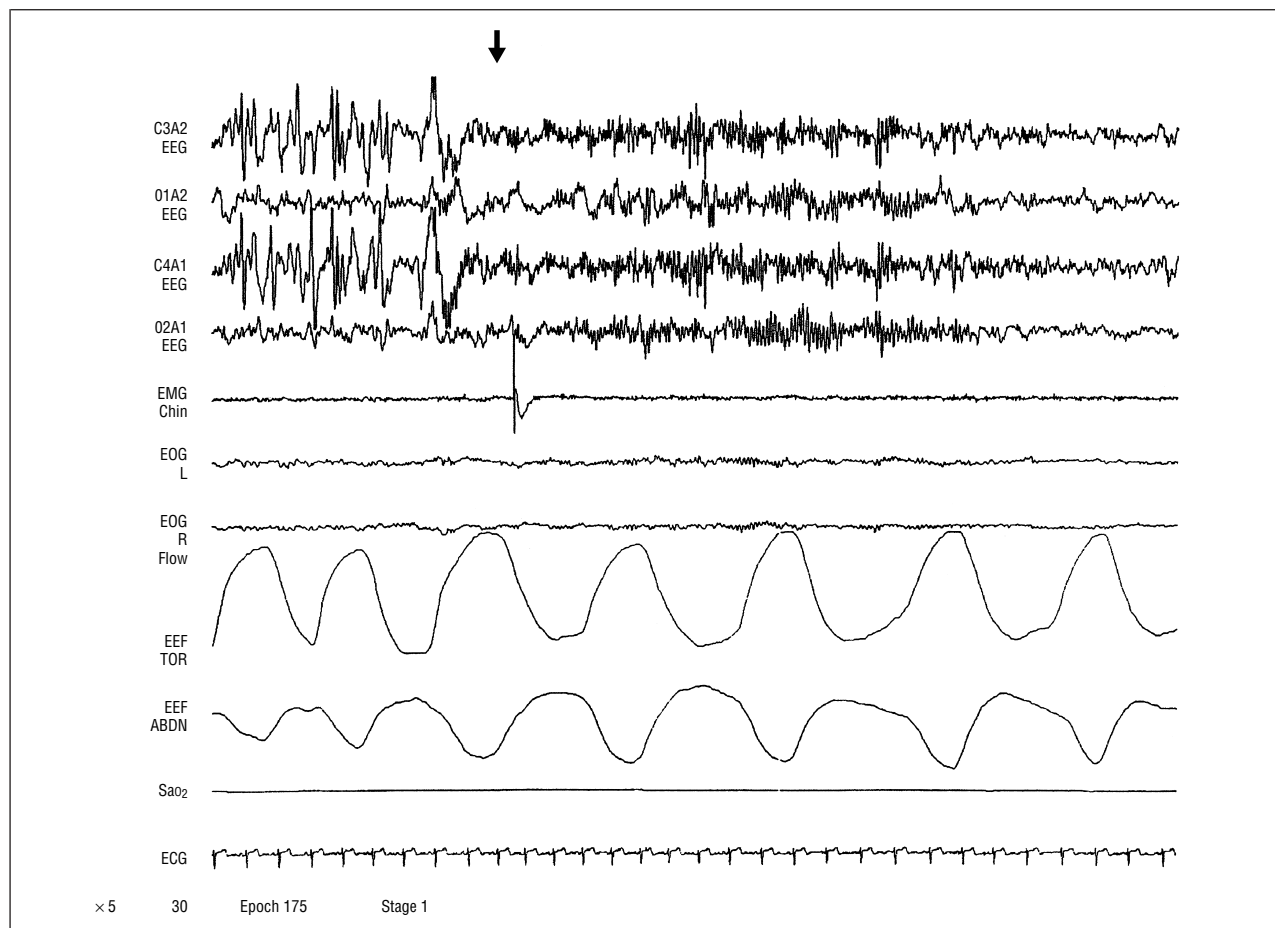
The following variables were analyzed: total recording time, total sleep time, sleep efficiency (total sleep time per total recording time), sleep architecture (percentages of sleep stages), number of awakenings, total number of arousals, arousal index (number of arousals per hour of total sleep time), number of respiratory arousals, wakefulness during sleep, apnea-hypopnea index (AHI) (total number of scored apneas and hypopneas divided by the number of hours of sleep), SaO₂ baseline and SaO₂ nadir (lowest value during total sleep time), percentage of total recording time with the SaO₂ level exceeding 90%, and oxygen desaturation index (number of oxygen desaturations per hour).

STATISTICAL ANALYSIS

Statistical analyses and the calculations were performed using SPSS for Windows, Version 9.0 (SPSS, Chicago, Ill). All results are expressed as mean (SD). The nonparametric Mann-Whitney test was used for the comparison of quantitative variables between the groups of snorers vs nonsnorers (controls) as well as between snorers with an AHI of 2 or more vs nonsnorers with an AHI of less than 2. The strength of the association between variables was assessed by the Pearson correlation coefficient. Statistical significance was set at $P < .05$.

RESULTS

The study population consisted of 43 adolescents, 24 boys and 19 girls who had a mean (SD) age of 13.6 (1.77) years (age range, 11-19 years). There were no



Polysomnographic tracing showing 1 arousal (arrow). ECG indicates electrocardiogram; EEFTOR, thoracic effort; EEG, electroencephalogram; EOG, electro-oculogram; and SaO₂, arterial oxygen saturation.

differences between male and female subjects for polysomnographic variables except for total sleep time, which was significantly shorter in girls (343.37 [36.57] minutes) than in boys (375 [71.35] minutes) ($P < .03$) (**Table 1**).

Results of polysomnography in snorers ($n = 28$) and nonsnorers ($n = 15$) are given in **Table 2**. There were no statistically significant differences between both groups in the percentages of sleep stages, arousal index, awakenings, or wakefulness during sleep. Snorers showed a significantly higher number of respiratory arousals than nonsnorers (1.14 [1.5] vs 0.33 [0.6], $P < .047$). However, neither the AHI nor the oxygen desaturation index correlated with the arousal index.

Of the total number of 43 adolescents included in the study, there were 12 snorers (27.5%) who had an AHI of 2 or more and 13 nonsnorers (30.2%) with an AHI of less than 2. Snorers with some obstructive respiratory events had a significantly higher number of awakenings, a lower percentage of stage 4 sleep, and a higher number of respiratory arousals compared with nonsnorers with an AHI of less than 2 (**Table 3**). However, the total number of arousals and the arousal index was similar in both groups. Wakefulness during sleep tended to be longer in snorers who had an AHI of 2 or more than in nonsnorers who had an AHI of less

than 2, although differences were not statistically significant. The percentage of respiratory events that terminated with an arousal was greater in snorers who had an AHI of 2 or more than in nonsnorers who had an AHI of less than 2 (8.4% [9.5%] vs 4.9% [11.53%], $P < .05$).

COMMENT

In this study we have evaluated the influence of snoring and respiratory events on the distribution of sleep stages and sleep architecture in a nonselected group of adolescents from the general population. In contrast to adults, snorers in the adolescent age group including those with some respiratory events in the polysomnography did not show relevant changes in sleep architecture; however, snorers with polysomnographic abnormalities showed a higher number of arousals associated with respiratory events and a decrease in the percentage of stage 4 sleep compared with nonsnorers.

For the definition of respiratory events, we used a minimal duration of 5 seconds instead of 10 seconds accepted for adults because in previous studies carried out by our group in children, it was found that this short obstructive event may cause falls in SaO₂ levels,^{12,13} and, thus, are clinically important. The clinical significance of short

Table 1. Differences in Polysomnographic Variables by Sex*

Variables	Male Patients (n = 24)	Female Patients (n = 19)	P Value
Total recording time, min	397.00 (36.60)	395.00 (33.64)	.98
Total sleep time, min	375.00 (71.35)	343.37 (36.57)	.03
Sleep efficiency, %	91.37 (6.65)	87.26 (9.30)	.13
Awakenings, No.	2.65 (3.79)	2.37 (3.37)	.56
Arousal, No.	36.79 (14.74)	30.00 (12.9)	.14
Arousal index	5.97 (2.30)	5.32 (2.30)	.31
Respiratory arousals, No.	0.95 (1.60)	1.73 (0.8)	.49
Wake during sleeping, min	27.71 (24.21)	38.68 (31.34)	.32
Sleeping stages, % total sleep time			
Stage 1	11.33 (9.54)	11.00 (5.73)	.65
Stage 2	43.25 (10.53)	44.63 (9.34)	.8
Stage 3	13.54 (5.88)	11.05 (4.73)	.12
Stage 4	12.17 (8.05)	11.63 (6.16)	.78
REM, % total sleep time	15.00 (11.91)	11.63 (4.47)	.33
AHI	1.87 (1.48)	1.81 (1.20)	.97
Oxygen desaturation index	0.02 (0.08)	0.1 (0.20)	.23
SaO ₂ nadir, %	92.3 (2.72)	91.11 (4.71)	.52

Abbreviations: AHI, apnea-hypopnea index; REM, rapid eye movement; SaO₂, arterial oxygen saturation.

*Data are given as mean (SD). Boldfaced P value indicates statistical significance.

Table 2. Comparison of Polysomnographic Variables in Snorers and Nonsnorers*

Variables	Snorers (n = 28)	Nonsnorers (n = 15)	P Value
Total recording time, min	399.00 (35.81)	390.00 (33.53)	.38
Total sleep time, min	368.00 (67.03)	348.00 (43.93)	.29
Sleep efficiency, %	89.67 (8.06)	89.33 (8.51)	.89
Awakenings, No.	3.04 (4.04)	1.50 (1.95)	.18
Arousals, No.	34.14 (13.99)	33.13 (15.09)	.82
Arousal index	5.68 (2.40)	5.69 (2.32)	.73
Respiratory arousals, No.	1.14 (1.50)	0.33 (0.60)	.047
Wake during sleep, min	34.57 (29.21)	28.8 (25.45)	.52
Sleep stages, % total sleep time			
Stage 1	10.75 (5.78)	12.00 (11.24)	.63
Stage 2	44.71 (11.09)	42.27 (7.37)	.44
Stage 3	11.96 (5.10)	13.33 (6.23)	.44
Stage 4	10.64 (6.75)	14.33 (7.63)	.11
REM, % total sleep time	13.07 (5.07)	14.33 (7.63)	.68
AHI	2.02 (1.31)	1.51 (1.44)	.24
Oxygen desaturation index	0.03 (0.01)	0.10 (0.22)	.98
SaO ₂ nadir, %	91.5 (3.93)	92.40 (3.40)	.45

Abbreviations: AHI, apnea-hypopnea index; REM, rapid eye movement; SaO₂, arterial oxygen saturation.

*Data are given as mean (SD). Boldfaced P value indicates statistical significance.

apneas also has been emphasized by others.⁵ We choose to perform the polysomnographic recording using a thermistor for oronasal flow. Although this technique is known to have limitations in detecting obstructive events,^{14,15} it is relatively noninvasive and, thus, does not disturb sleep. Esophageal probes may measure respiratory effort more accurately, but they significantly interfere with sleep efficiency in the pediatric population.⁴

Table 3. Comparison of Polysomnographic Variables in Snorers With an AHI of 2 or More With Nonsnorers With an AHI of Less Than 2*

Variables	Snorers With an AHI of ≥2 (n = 12)	Nonsnorers With an AHI of <2 (n = 13)	P Value
Total recording time, min	399.54 (35.09)	385.33 (35.44)	.4
Total sleeping time, min	356.92 (36.92)	351.5 (45.15)	.85
Sleep efficiency, %	89.46 (6.35)	91.08 (6.96)	.34
Awakenings, No.	5.23 (4.95)	1.36 (1.57)	.02
Arousals, No.	36.23 (10.96)	36.17 (13.31)	.85
Arousal index	6.15 (2.05)	6.13 (1.92)	.93
Respiratory arousals, No.	1.53 (1.80)	0.25 (0.62)	.01
Wake during sleep, min	36.62 (28.55)	24.83 (22.91)	.09
Sleep stages, % total sleep time			
Stage 1	10.62 (4.96)	8.92 (3.48)	.53
Stage 2	45.46 (10.52)	42.67 (5.87)	.37
Stage 3	11.69 (5.20)	14.33 (6.62)	.43
Stage 4	12.69 (4.27)	16.42 (6.69)	.03
REM, % total sleep time	12.69 (4.27)	11.17 (3.64)	.32
AHI	3.10 (1.08)	0.9 (0.42)	<.001
Oxygen desaturation index	0.03 (0.07)	0.06 (0.17)	.93
SaO ₂ nadir, %	90.46 (5.08)	92.5 (3.66)	.37

Abbreviations: AHI, apnea-hypopnea index; REM, rapid eye movement; SaO₂, arterial oxygen saturation.

*Data are given as mean (SD). Boldfaced P values indicate statistical significance.

We used an AHI of 2 or more as the cutoff point because the mean value in our series was 1.8 (1.3) (range, 0-5.8). Most AHI values were within the range of normal data according to a study carried out by Acebo et al¹⁶ in which the mean value of the AHI in a healthy adolescent and young adult population was 1.3 (1.3). Our values are slightly higher probably because no inclusion or exclusion criteria were applied in the present study. However, since normative data regarding polysomnographic characteristics in the adolescent age group have not been standardized, decisions for establishing cutoff points are arbitrary.

In the pediatric population, different criteria for the definition of arousals are used and interpretations regarding normal values and their precise clinical significance are controversial.¹⁶ The 2 classifications more widely used are that of Rechtschaffen and Kales⁹ and that proposed by the American Sleep Disorders Association,¹⁰ which was the definition used in this study.

Normal electroencephalographic characteristics in adolescence are not well known, although a few studies have been carried out. Kahn et al¹⁷ reviewed the literature and collected data on normal sleep architecture along different developmental stages, from neonates to adolescents, and found that electroencephalographic features of adolescents were similar to those of young adults. Slow wave sleep decreases progressively according to pubertal Tanner stages (about 35% decrease from stage 1 to stage 5 sleep). On the other hand, the distribution of REM and non-REM sleep has shown similar values than what is seen in adults, and REM sleep periods are more prolonged during the second half of the night.¹⁸ In our series, the percentages of each sleep stage

were similar to those reported by other authors in studies of adolescents,⁶ although the proportion of REM sleep in our study was slightly lower (15% of the total sleep time) compared with results of the study of Acebo et al⁶ (17.7% of total sleep time). The arousal index was also similar to that reported by others.⁶

The mean time of sleep, in our study, was longer than 6 hours, with a mean sleep efficiency of 89%. Boys showed a mean duration of total sleep time slightly higher than girls (375 minutes vs 343 minutes, $P=.03$), without differences in sleep efficiency. Gau and Soong¹⁹ in a large sample of adolescents found a lower number of sleep hours among girls, although no differences were found between both sexes in excessive daytime sleepiness. In our series, no differences in the distribution of sleep stages or in the number of arousals between boys and girls were noted.

The relationship between SRBDs and sleep architecture in adults is well known. Adults with SRBDs usually present multiple arousals secondary to repetitive increases in respiratory effort during obstructive respiratory events causing sleep fragmentation and a reduction of the percentages of non-REM stages 3 and 4 and REM sleep.^{20,21} Polysomnographic changes in children with SRBDs are different than those found in adults.²² With regard to neurophysiologic factors in children, obstructive respiratory events do not frequently terminate with a cortical arousal and, consequently, sleep architecture is usually preserved.²³ In this respect, Goh et al⁴ carried out a retrospective study of 20 children diagnosed as having obstructive sleep apnea syndrome by standard polysomnography compared with healthy controls. There were no differences in the distribution of sleep stages or in the degree of sleep fragmentation between patients with obstructive sleep apnea syndrome and controls. These results are in accord with other studies in which it has been shown that there are no changes in sleep architecture after adenotonsillectomy in children with obstructive sleep apnea syndrome.^{24,25} However, in other studies of children with polysomnographic confirmation of obstructive sleep apnea syndrome, a higher number of spontaneous and movement arousals has been reported than seen in controls.²⁶

In adolescents, the influence of snoring and respiratory events on sleep architecture is unknown. In this series, we have not found important alterations of sleep architecture; the findings from all study subjects indicated that sleep macroarchitecture and microarchitecture were within normal limits. Most obstructive respiratory events did not terminate in a respiratory arousal, which suggests that neurophysiologic response to these events in adolescents from the general population is similar to that already known for younger children.⁴ Snorers and nonsnorers from the adolescent age group had similar polysomnographic characteristics, except for a higher number of respiratory arousals among snorers. These findings suggest that in snorers from the adolescent age group, there may be some episodes of increased resistance of the upper airway that are not detected by the thermistor signal. Snorers with an AHI of 2 also had a higher number of respiratory arousals than controls. Moreover, there were more episodes of

What This Study Adds

It is known that clinical and polysomnographic characteristics of children with SRBDs differ from those found in adults. In adolescents, no systematic studies assessing the influence of snoring and respiratory events on sleep architecture have been performed. Data from this study indicate that adolescents from the general population show a normal sleep architecture and that neurophysiologic response to respiratory events is similar to that already known for younger children.

awakenings and a slightly lower percentage of non-REM stage 4 sleep. This finding would be consistent with what is known for younger children with SRBDs, in which REM sleep tends to be preserved.²⁷

Data from this study indicate that adolescents from the general population show a normal sleep architecture. Although snorers and adolescents with some polysomnographic abnormalities showed a higher number of respiratory arousals than controls, most obstructive events did not terminate with a cortical arousal, which may suggest that adolescents share with younger children this mechanism for preserving sleep architecture. However, it cannot be discarded that children and adolescents with SRBDs may present subtle electroencephalographic changes that cannot be detected by the standard techniques and conventional criteria used for adults.^{14,28} It may also be possible that subcortical or autonomic arousals may play an important role as a response to apneic activity in the adolescent population.²⁹

Finally, adolescents in this study were selected from the general population and showed slight polysomnographic changes, so that it cannot be excluded that patients with severe SRBDs in this age group might experience sleep architecture alterations similar to those reported in adults with SRBDs.

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