Reliability of Scoring Arousals in Normal Children and Children with Obstructive Sleep Apnea Syndrome

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Study Objectives: Scoring of arousals in children is based on an extension of adult criteria, as defined by the American Sleep Disorders Association (ASDA). By this, a minimum duration of 3 seconds is required. A few recent studies utilized modified criteria for the study of children, with durations as short as 1 second. However, the validity and reliability of scoring these shorter arousals have never been verified. Based on studies in adults, we hypothesized that interscorer agreement for scoring arousals shorter than 3 seconds was poor.

Design: Retrospective review of polysomnograms by 2 experienced sleep practitioners who independently scored arousals according to the ASDA 3-second criteria and modified duration criteria of 1 and 2 seconds.

Setting: Academic hospital.

Patients or Participants: 20 polysomnographic studies from children aged 3 to 8 years with mild to severe obstructive sleep apnea syndrome, and 16 polysomnographic studies from normal children.

Interventions: None.

Measurements and Results: The intraclass correlation coefficient for scoring ASDA arousals was 0.90 (95% confidence interval: 0.81-0.95), indicating excellent interscorer agreement. The intraclass correlation coefficient for scoring modified 1-second and 2-second arousals were 0.35 (95% confidence interval: 0.02-0.61) and 0.42 (95% confidence interval: 0.12-0.65) respectively, indicating poor to fair interscorer agreement. Furthermore, modified 1-second and 2-second arousals accounted for less than 15% of all arousals scored.

Conclusions: We conclude that there is much poorer interscorer agreement for scoring arousals shorter than 3 seconds, when compared to the standard ASDA criteria. We propose that scoring of arousals in children should follow the standard ASDA criteria.

Key Words: Human; children; sleep; polysomnography; arousal; scoring methods; reliability and validity

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INTRODUCTION

THE OBSTRUCTIVE SLEEP APNEA SYNDROME (OSAS) IS ASSOCIATED WITH EPISODIC UPPER-AIRWAY OBSTRUCTION THAT CAN BE ASSOCIATED WITH HYPOXEMIA, HYPERCAPNIA, AND AROUSAL. Although arousals occur less frequently in children than in adults, apneas in children may nevertheless terminate in association with electroencephalographic (EEG) arousals.[1] Arousal is believed to be an important protective mechanism for terminating obstructive apnea, thus reestablishing the patency of the upper airway and protecting the body against severe hypoxemia.[2] However, increased arousal frequency has been linked to sleep fragmentation, daytime neurobehavioral impairment, and autonomic consequences.[3-5] It is therefore important to quantify arousals accurately in polysomnography.

In adults, arousal is defined according to the American Sleep Disorders Association (ASDA) criteria.[6] By these criteria, arousal is defined as an abrupt shift in EEG frequency, which may include theta, alpha, and/or frequencies greater than 16 Hz but not spindles. Other criteria include (1) a minimum of 10 continuous seconds of preceding sleep, (2) a concurrent increase in submental electromyogram (EMG) amplitude in rapid eye movement (REM) sleep, and (3) a minimum duration of 3 seconds in the EEG frequency shift. The 3-second minimal duration was chosen essentially based on pragmatic methodologic reasons as opposed to a physiologic basis.[6] In practice, arousals shorter than 3 seconds do exist. However, because of the technical difficulty in scoring such arousals, interscorer variability has been very large.[7,8]

There has been no consensus regarding the scoring of arousals in children. Most investigators have used the adult criteria, sometimes with modifications.[1,9-12] Since the sleep EEG pattern changes significantly with age, the pattern of arousals may be different in both duration and the frequencies of EEG shift.[12] Furthermore, shorter clinical apneas are considered clinically significant in children as compared to adults.[13] Because of this, some researchers have chosen to measure EEG arousals as short as 1 second in duration.[9,14] However, the validity of this approach has not been tested. It is not known how accurately these short arousals can be measured or what degree of interscorer variability exists. In studies of adults, the literature has indicated that agreement on scoring arousals shorter than 3 seconds is difficult to achieve.[6,7]

We hypothesized that interscorer agreement for scoring arousals shorter than 3 seconds is poor. Thus, the primary aim of the study was to determine the interscorer agreement between experienced observers on the scoring of arousals of different durations in children. The secondary aim was to gather data on the frequency of arousals shorter than 3 seconds and the frequency of spontaneous arousals in children.

Disclosure Statement

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METHODS

Study Design

We performed a retrospective review of 36 polysomnographic studies from children with OSAS and normal children. Two experienced sleep practitioners independently reviewed the studies and scored arousals of 1, 2, and 3 seconds in duration.

Subjects

Subjects in the OSAS group were obtained from our polysomnographic database of children evaluated for clinically suspected OSAS over a 1-year period from January 1, 2001 to December 31, 2001. Patients meeting the age and inclusion criteria below were selected. Patients were further screened by a review of their medical records, according to inclusion and exclusion criteria. Inclusion criteria included (1) age between 3 and 8 years, so as to cover the peak age group for OSAS in children and (2) OSAS as diagnosed on overnight polysomnography, with an apnea hypopnea index (AHI) of at least 5 events per hour. Exclusion criteria included (1) significant neurologic disease, (2) significant concomitant medical illness, (3) obesity as defined by a body mass index ≥ 97th percentile,[15] (4) on long-term medication affecting sleep, and (5) total duration of REM sleep during polysomnography less than 60 minutes or less than 10% of total sleep time.

The quality of the tracings was screened independently. Only studies with high-quality EEG tracings throughout the night were used. Those studies with intermittent electrode popping, loss of leads, or areas of artifact were excluded.

The normal group comprised of a group of healthy nonsnoring children aged 3 to 8 years, recruited from the community as controls for other research studies.[16-18] Because of the limited number of subjects in the normal group, the 2 groups were not age-matched. Therefore, a subgroup analysis was performed for age-matched comparison between the OSAS group and the normal group for analysis of the secondary outcomes.

Polysomnography

All polysomnographic studies were performed overnight at the Johns Hopkins Pediatric Sleep Center.[13] Each subject was monitored with EEG (C3/A2, C4/A1 and O1/A2), right and left electrooculogram, and submental EMG. Electrocardiogram was monitored continuously. Arterial oxygen saturation and oximeter pulse waveform were monitored continuously with a pulse oximeter (Nellcor N-1000, Van Nuys, Calif). End-tidal PCO_2 was measured continuously at the nose by infrared capnometry (Nellcor N-1000). These studies were performed before measurement of nasal pressure started being used in children. Thus, oronasal airflow was measured using a 3-pronged thermistor. Chest and abdominal wall movements were measured using piezoelectric belts or respiratory inductance plethysmography. Leg movements were monitored with EMGs. The subject was also videotaped.

All signals were amplified, filtered, and recorded using an Alice 3 polysomnographic recorder (Respironics, Murrysville, Penn). The study commenced at approximately 8:00 PM to 9:00 PM and was terminated at approximately 6:00 AM. All subjects were monitored continuously throughout the study by a polysomnography technician who marked observations and all interventions in the Alice 3.

Data Analysis

The polysomnographic record was scored for sleep stages according to the standard Rechtschaffen and Kales criteria, using 30-second epochs.[19] Respiratory events were scored according to standard criteria for children.[13,20] Obstructive apnea was defined as cessation of airflow lasting for 2 breaths or longer, in the presence of paradoxical rib cage and abdominal movements. Hypopnea was defined as a clear amplitude reduction of the thermistor signal by more than 50% and accompanied by either oxygen desaturation or arousal.[21] Central apnea was defined as absence of airflow at both the nose and mouth and movements of chest wall and abdomen, lasting 20 seconds or more, or accompanied by oxygen desaturation. Mixed apnea was defined as apnea with both central and obstructive components. Oxygen desaturation was defined as a drop in SaO_2 of 3% or more, or sustained values of less than 92%.[20] The obstructive apnea index was defined as the number of obstructive and mixed apneas, with a duration of at least 2 respiratory cycles, per hour of total sleep time.[13,22] The apnea-hypopnea index was defined as the number of obstructive and mixed apneas and hypopneas per hour of total sleep time.

Each study was then scored independently by 2 investigators (TKW and PG) after completion of sleep staging and scoring of respiratory events. Both investigators were experienced with reading and scoring pediatric sleep studies. One scorer was a pediatric pulmonologist with expertise in sleep medicine; the other was a registered polysomnographic technologist with more than 10 years experience in scoring pediatric sleep studies. Arousal scoring was performed using a standardized screen resolution of 1600 × 1200 pixels using the Alice polysomnography system. Scoring was done on both the central and occipital EEG leads, with full visualization of respiratory channels, using 30-second epochs. Scorers were allowed to change to 10-second epochs for verification, where appropriate.

Each study was scored to include all arousals meeting the ASDA criteria but lasting for longer than 1 second. Arousals were then counted and classified into 3 types according to their duration: (1) arousals meeting all the ASDA criteria except that they were at least 1 second but less than 2 seconds in duration (1-second arousal); (2) arousals meeting all the ASDA criteria except that they were at least 2 seconds but less than 3 seconds in duration (2-second arousal); (3) arousals meeting the standard ASDA criteria (ASDA arousal).[6]

Arousals were further classified into 3 subtypes according to their relationship to obstructive events: (1) arousals occurring within 2 seconds of the termination of an obstructive apnea or hypopnea (respiratory-related arousal); (2) arousals not associated with or occurring 2 or more seconds after termination of an obstructive apnea or hypopnea (spontaneous arousal); (3) arousals that occurred while the technician was in the room or manipulating the leads, as indicated in the comments by the technician (technician-related arousal).

All arousal subtypes were included in the primary analysis, ie, the analysis of interscorer agreement. However, the technician-related arousals were excluded from the secondary analysis, ie, the comparison between the OSAS and control groups.

Statistical Analysis

Arousal indexes, expressed as the number of arousals per hour of total sleep time, were calculated for each subtype of arousal. Data are displayed as mean ± SD where appropriate. We compared continuous data using the unpaired *t* tests, and discrete data using the χ^2 test. The degree of agreement between results from the 2 investigators was analyzed using the intraclass correlation coefficient (ICC).[23] The definitions of poor agreement (ICC < 0.4), fair to good agreement (0.4 ≤ ICC < 0.75), and excellent agreement (ICC ≥ 0.75) were proposed by Fleiss.[24] Statistical analysis was performed using the SPSS statistical software package (SPSS for Windows 9.0, SPSS Inc, Chicago, Ill). A *P* value of < .05 was considered statistically significant.

RESULTS

A total of 29 children matched the inclusion and exclusion criteria for the OSAS group and 16 for the normal group. In the OSAS group, 9 studies were excluded. Eight were excluded because of the presence of artifact in the EEG tracing. The ninth study was excluded because of prolonged episodes of alpha intrusion throughout the night. Thus, a total of 36 polysomnographic studies were available for arousal scoring. The demographic data and polysomnographic index are shown in Table 1. The distribution of AHI is shown in Figure 1. The OSAS in this group of children represented a range from normal to severe.

Arousals

When evaluating all arousals ≥ 1 second for the 36 polysomnographic studies, TKW scored 1875 (74%) spontaneous arousals, 541 (21%) respiratory-related arousals, and 131 (5%) technician-related arousals. PG scored 1620 (69%) spontaneous arousals, 630 (27%) respiratory-related arousals, and 107 (5%) technician-related arousals. The arousal indexes are shown in Table 2. The ASDA arousals were far more common than 1- and 2-second arousals.

The interscorer agreement was poor for scoring 1-second arousals, as shown in the scatter diagram (Figure 2A), with a low ICC (0.35; 95% confidence interval [CI]: 0.02, 0.61). Similarly, the interscorer agreement was only fair for scoring 2-second arousals (Figure 2B), with a low ICC (0.42; 95%CI: 0.12, 0.65). In contrast, the interscorer agreement was excellent for ASDA arousals (Figure 2C), with an ICC of 0.90 (95%CI: 0.81, 0.95) (Table 2).

We found similar results when we evaluated the normal group alone (n = 16). The interscorer agreement was poor for 1-second arousals, with an ICC of 0.21 (95%CI:-0.21, 0.56); poor to fair for 2-second arousals, with an ICC of 0.40 (95%CI:-0.10, 0.75); and excellent for ASDA arousals, with an ICC of 0.88 (95%CI:0.69, 0.96).

Comparison Between the Normal and OSAS Groups

To look at the secondary outcome, we compared arousal data between the normal and the OSAS groups scored by PG alone. A total of 22 children were included in the age-matched subgroup analysis, with 11 subjects in each group. The baseline demographic data and sleep architecture were similar between the 2 groups. As expected, the OSAS group had higher apnea indexes and lower arterial SaO_2 (Table 3).

For the ASDA arousals, the arousal index was 9.2 ± 3.7 per hour in the OSAS group versus 7.6 ± 3.4 per hour in the normal

Table 1—Demographic and Polysomnographic Data of All Children

Number	36
Age, y	5.3 ± 1.4
Sex, boys/girls	18/18
Race, Caucasian/African American	16/20
Body mass index, kg/m²	17.0 ±3.3
TST, min	399 ± 48
Sleep efficiency, %	87 ± 9
Wake after sleep onset, min	32 ± 39
Awakenings, no./h	1.1 ± 0.7
Sleep-stage duration, as a percentage of TST	
Stage 1	4 ± 3
Stage 2	45 ± 8
Slow-wave sleep	30 ± 6
REM	21 ± 6
REM episodes, no.	5 ± 3
Central apnea, no./h	0.3 ± 0.5
Apnea index, no./h	6.0 ± 11.4
Apnea hypopnea index, no./h	7.8 ± 14.5
Nadir SaO_2, %	87 ± 14
Maximum end-tidal PCO_2, mmHg	50 ± 5

Data are shown as mean ± SD where appropriate.
TST refers to total sleep time; REM, rapid eye movement.

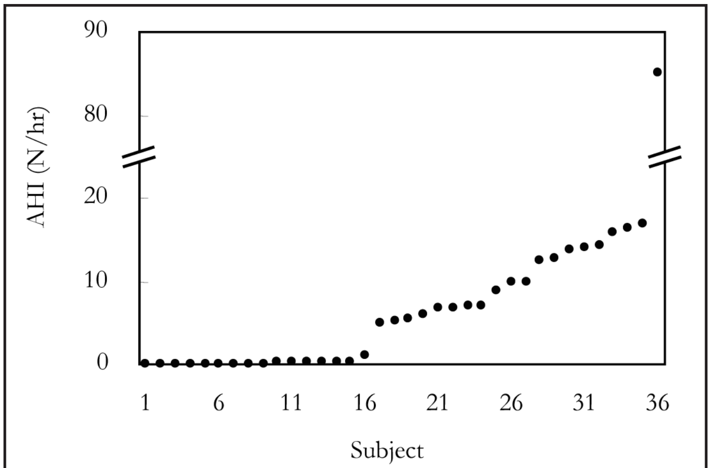

Figure 1—Distribution of apnea-hypopnea indexes (AHI) of all children (n = 36)

Table 2—Comparison of Arousal Indexes Scored by 2 Investigators and the Intraclass Correlation Coefficients

	Mean ± SD Arousal Index, no./h TKW	PG	ICC (95%CI)
1-second arousal	1.1 ± 0.9	0.6 ± 0.5	0.35 (0.02, 0.61)
2-second arousal	0.9 ± 0.6	0.7 ± 0.5	0.42 (0.12, 0.65)
ASDA arousal	8.5 ± 4.0	8.5 ± 3.6	0.90 (0.81, 0.95)

ICC refers to intraclass correlation coefficient; 95%CI, 95% confidence interval. TKW and PG are the 2 investigators.

A 1-second arousal is defined as an arousal meeting the American Sleep Disorders Association (ASDA) criteria but lasting only 1 to 2 seconds; a 2-second arousal is defined as an arousal meeting the ASDA criteria but lasting only 2 to 3 seconds.

group (NS). The spontaneous ASDA arousal index was 4.4 ± 2.0 per hour in the OSAS group versus 7.0 ± 3.9 per hour in the normal group (NS) (Figure 3). The respiratory-related ASDA arousal index was 4.8 ± 4.8 per hour in the OSAS group, as compared with 0.2 ± 0.2 per hour in the normal group ($P < .01$). Data for REM versus non-REM sleep are shown in Table 4. During both REM and non-REM sleep, children with OSAS had a higher respiratory arousal index than children in the normal group. Surprisingly, the normal group had a higher spontaneous ASDA arousal index than the OSAS group during REM sleep.

Arousals (both spontaneous and respiratory-related) lasting at least 1 second and less than 3 seconds accounted for 15% of all arousals lasting 1 second or longer in the OSAS group, and 8.5% in the normal group. In the OSAS subgroup, 63% of all obstructive events were not followed by arousal, 6% of all obstructive events were followed by arousals lasting 1 second or more but less than 3 seconds, and 31% all obstructive events were followed by ASDA arousals (Figure 4).

DISCUSSION

Arousals from sleep are important clinically because of their link to sleep fragmentation and daytime neurobehavioral disturbances. However, further delineation of the relationship between

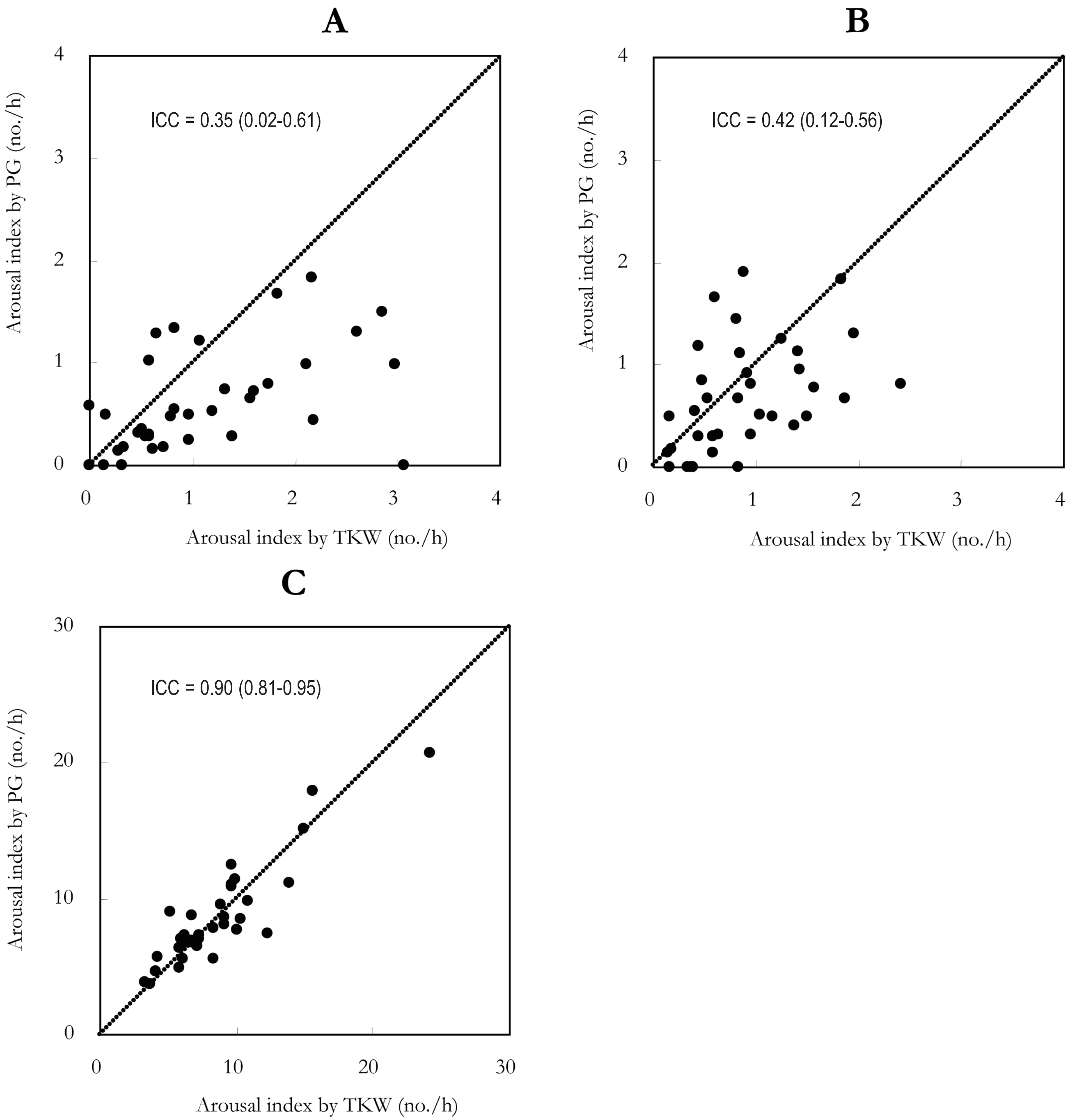

Figure 2—Relationship between arousal indexes scored by 2 investigators (TKW and PG). A: 1-second arousal; B: 2-second arousal; C: American Sleep Disorders Association arousal. The line of identity and intraclass correlation coefficient (ICC) with 95% confidence intervals are shown..

the frequency of arousals and their physiologic consequences in children has been limited by lack of standardization and difficulty accurately quantifying arousals. To our knowledge, our study is the first study designed to systematically look at the reproducibility of scoring ASDA arousals versus shorter arousals in children.

The ASDA criteria for scoring arousals have been adopted as the standard for assessment of arousal in adults.[6] In adults, Drinnan[8] reported moderate interscorer agreement with κ of 0.47. A high interscorer reliability was reported by Loredo[7] and Smurra,[25] with an ICC of 0.84 and 0.96, respectively. In all 3 studies, the scorers were allowed to visualize the relevant EEG and EMG tracings only. In another study, Whitney[26] reported moderate agreement with an ICC of 0.54 based on scoring of unattended studies using only central EEGs. The results from the current study showed strong interscorer agreement with an ICC of 0.90, thus providing further support for the validity of application of the ASDA criteria. Although visualization of respiratory tracings may provide clues to arousal scoring, it is not the major determining factor, as we also found a strong interscorer agreement (ICC = 0.88) in scoring ASDA arousals in the normal group.

Several studies in children have included analysis of arousals shorter than 3 seconds.[1,9,11,27] This approach may sound reasonable because shorter apneas are believed to be clinically significant in children. However, even if there is a theoretical reason for scoring short arousals, if the scoring cannot be accurate with the available technology, then the data will be meaningless. We found that interscorer agreement for short arousals was only poor to fair, with ICCs of 0.35 and 0.42 for 1-second and 2-second arousals, respectively. This was in strong contrast with the good interscorer agreement for ASDA arousals in the same study. Similar results have been reported by other authors evaluating adults. Loredo[7] reported ICCs of 0.19 to 0.37 for arousals lasting at least 1.5 seconds but less than 3 seconds. Thus, we did find evidence to support the finding that duration of arousal is an impor-

Table 3—Demographic and Polysomnographic Data of age-Matched Group with Obstructive Sleep Apnea Syndrome and Normal Group

	OSAS group	Normal group
Number	11	11
Age, y	5.5 ± 0.7	5.6 ± 1.1
Sex, boys/girls	5/6	7/4
Race, Caucasian/African American	4/7	6/5
Body mass index, kg/m^2	18 ± 5	16 ± 1
TST, min	396 ± 51	418 ± 50
Sleep efficiency, %	87 ± 6	89 ± 7
Wake after sleep onset, min	18 ± 13	23 ± 31
Awakenings, no./h	1.0 ± 0.6	0.9 ± 0.7
Sleep-stage duration, as a percentage of TST		
Stage 1	3 ± 3	5 ± 3
Stage 2	43 ± 8	49 ± 7
Slow-wave sleep	32 ± 6	27 ± 8
REM	23 ± 8	20 ± 4
REM episodes, no.	5 ± 3	6 ± 3
Central apnea, no./h	0.3 ± 0.5	0.1 ± 0.1
Apnea index, no./h	13.6 ± 17.9	0.0 ± 0.0*
Apnea hypopnea index, no./h	17.9 ± 22.7	0.0 ± 0.1*
Nadir SaO_2, %	74 ± 20	95 ± 3 **
Maximum end-tidal PCO_2, mmHg	54 ± 5	47 ± 4 **

Data are shown as mean ± SD where appropriate.
OSAS refers to obstructive sleep apnea syndrome; TST, total sleep time; REM, rapid eye movement.
*$P < .05$
**$P < .01$

Table 4—Arousal Indexes During Non-Rapid Eye Movement and Rapid Eye Movement Sleep in Age-Matched Obstructive Sleep Apnea Syndrome Group and Normal Group

	Arousal Index, no./h	
	Normal group	OSAS group
Non-REM Sleep		
Total	6.0 ± 2.4	8.0 ± 3.2*
Spontaneous arousal	5.8 ± 2.4	5.5 ± 2.8
Respiratory-related arousal	0.2 ± 0.3	2.4 ± 1.7**
REM Sleep		
Total	10.8 ± 7.9	11.6 ± 9.4
Spontaneous arousal	10.1 ± 8.0	4.2 ± 2.4**
Respiratory-related arousal	0.7 ± 0.9	7.4 ± 9.2**

Data are shown as mean ± SD.
OSAS refers to obstructive sleep apnea syndrome; REM, rapid eye movement.
*$P < .05$ for OSAS group vs normal group.
**$P < .01$ for OSAS group vs normal group.

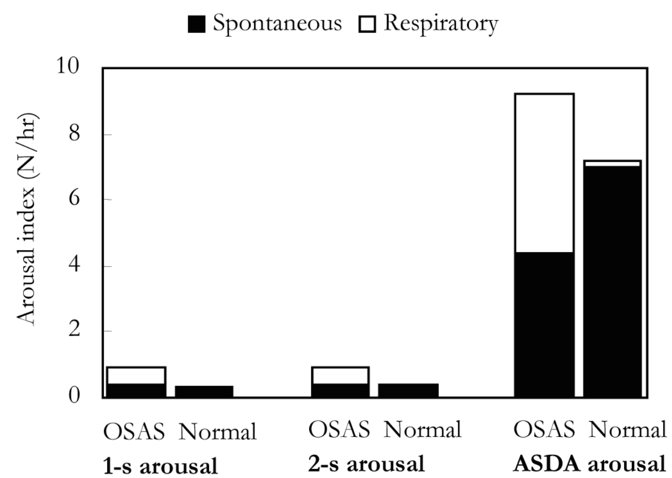

Figure 3—Arousal indexes in the group with obstructive sleep apnea syndrome (OSAS) and the group of age-matched normal controls. ASDA refers to American Sleep Disorders Association.

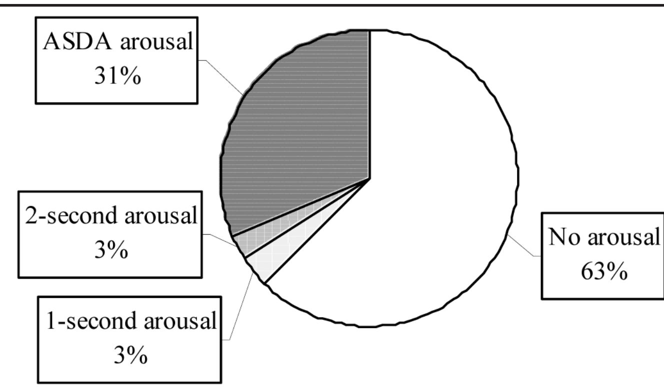

Figure 4—Percentage of obstructive events followed by arousals in the group with obstructive sleep apnea syndrome. ASDA refers to American Sleep Disorders Association.

tant factor in interscorer agreement. Practically, we found it impossible to confidently distinguish short arousals from EEG artifact and incomplete sleep spindles in the absence of accompanying EMG changes. Therefore, at the present moment, scoring arousals shorter than 3 seconds based on EEG and EMG criteria alone is impractical even in the research setting. In contrast to the current study, Drinnan et al[8] did not find a relationship between arousal duration and interobserver variability. However, this publication evaluated arousals as long as 20 seconds and did not state the minimum duration of events evaluated; the mean duration of evaluated events was 7 ± 3 seconds. Thus, it is not clear whether this study evaluated brief events of less than 3 seconds in duration, although it may suggest that extending the duration of a defined event even longer than 3 seconds may not result in further improvements in interscorer variability.

The present study evaluated only normal children and children with OSAS. Thus, it is possible that these results may not be generalizable to children with other types of sleep disorders. However, this is unlikely, as it is not expected that the cause for arousal would alter the gross EEG morphology of the ASDA-type arousal. Furthermore, similar results were found for normal children and children with OSAS. Scoring of arousals was performed without blinding to the respiratory channels. However, this was unlikely to have affected the results, as similar results were found for normal children and children with OSAS.

In this study, we evaluated only those polysomnograms that were totally free of EEG artifact. Thus, it is probable that in general clinical practice, the scoring of short arousals would be even less reliable.

We found that the frequency of short arousals accounted for only 15% of all arousals. Although similar data have not been published in the pediatric population, Mathur et al[28] reported an arousal index of 26 per hour for modified 1.5-second criteria (ie all arousals ≥ 1.5 second) as compared with 21 per hour for standard ASDA criteria in their adult series. This gives rise to a rough estimation of the frequency of arousals lasting at least 1.5 second but less than 3 seconds, which would thereby account for approximately 20% of all the arousals scored. A similar trend was also seen in the arousals following obstructive events in the current study (6% of obstructive events terminated by 1-second or 2-second arousals versus 31% of obstructive events terminated by ASDA arousals). Given the relatively small proportion of these short EEG arousals, it is likely that the clinical significance of scoring them is limited.

A consensus on the definition of arousal in children has important implications on the quantification of respiratory events. Since hypopnea is defined based on a reduction of airflow and the presence of oxygen desaturation and/or arousal, extending the definition of arousal would result in increased scoring of hypopneas. Therefore, it would be advisable to use the ASDA criteria until any modification has been properly validated.

In the current study, the ASDA arousal index in the normal group was 7.6 ± 3.4 per hour. Similar data have been reported in the literature. Tasali et al[29] reported a mean arousal index of 7.2 per hour in children aged 0 to 5 years and 7.7 per hour in children aged 5 to 11 years. Bruni et al[30] reported a mean arousal index of 7.7 per hour in children aged 6 to 10 years. Stores et al[31] reported a mean arousal index of 9.3 per hour in children aged 5 to 7 years and 8.5 per hour in children aged 8 to 9 years. These results are higher than those reported by Acebo et al[32] (3.2 per hour in boys and 4.6 per hour in girls).

In the OSAS group, we found a mean ASDA arousal index of 9.2 ± 3.7 per hour. Different studies have shown a wide range of arousal indexes in children with OSAS.[1,9,11,33,34] Differences between studies are probably due to a number of factors, including the wide range of interindividual variability,[1,9] the different definitions of arousal used, differing severity of OSAS, different ages studied (as older children are more likely to arouse[1]), different sleep laboratory settings (eg, ambient noise level), and differing degree of instrumentation during polysomnography.

In both the OSAS and the normal groups, ASDA arousals occurred more frequently during REM than non-REM sleep. We found a lower frequency of spontaneous arousal in the OSAS group than in the age-matched normal group during REM sleep. The reason for this is unclear, but similar findings have also been reported in infants with OSAS.[1]

We realized the shortcoming of defining a respiratory arousal by its proximity to a respiratory event, as proximity does not necessarily imply a causal relationship. The use of more sophisticated techniques would be advantageous in future studies. We defined a respiratory arousal as one that occurred within 2 seconds of the termination of an apnea or hypopnea. There is no consensus definition on respiratory arousal. Some investigators have used 2 to 3 seconds as a cutoff point for adults.[26,35] In the acoustic stimulation model, arousals frequently occurred within 3 seconds of the initial acoustic stimuli.[36] We somewhat arbitrarily chose 2 seconds from the end of the obstructive event as the cutoff point, as children have a faster respiratory rate than do adults.

In the current study, airflow was measured using a combination of end-tidal PCO_2 and thermistry[13] rather than nasal pressure measurements. Although nasal pressure is now measured frequently during polysomnography in adults, several studies have shown that mouth breathing and nasal secretions limit its effectiveness in children.[37,38] Esophageal pressure measurements are invasive and are not used often.[39] However, it is possible that some arousals that were classified as spontaneous would have been determined to be respiratory in nature if more invasive measuring techniques had been used.

Since its publication, the ASDA arousal index has become the most widely accepted and applied index for scoring arousals. Recently, it has been realized that brainstem activation may play an important role in sleep-disordered breathing.[34,40-42] Thus, it is possible that the ASDA arousal index underestimates the true degree of arousal. Given the relatively small proportion of respiratory-related arousals as compared to spontaneous arousals, it is hard to believe that quantification of EEG arousals alone can adequately represent the degree of sleep fragmentation in children with OSAS. In the future, newer techniques, such as measurement of the cyclic alternating pattern, pulse transit time or sleep pressure score, may have greater potential in representing sleep fragmentation.[30,34,43,44]

Lastly, we did not analyze arousals related to central apnea because they were only present in a very small proportion of records. Technician-related arousal accounted for only 5% of all the arousals. This might be an underestimation because we relied on technician documentation for this determination.

In conclusion, we have shown that there is much poorer interscorer agreement for scoring arousals shorter than 3 seconds in children, when compared to the standard ASDA criteria. We propose that scoring of arousals in children should follow the standard ASDA criteria.

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