Outcomes from the Tucson Children’s Assessment of Sleep Apnea Study

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KEYWORDS
- Sleep-disordered breathing
- Children
- Epidemiology
- Learning
- Hypertension
- Behavior
- Ventilatory drive
- TuCASA

That sleep-disordered breathing (SDB) occurs in children has long been known. However, emerging recognition of the frequent occurrence and impact of SDB in the pediatric population has led to an increased clinical and academic interest in this condition. The presenting symptoms of childhood SDB include snoring, arousals, enuresis, restlessness during sleep, daytime sleepiness, and hyperactivity.1,2 Of particular importance is that, unlike SDB in adults, hyperactivity and not daytime sleepiness may be the most evident manifestation. Moreover, the presence of SDB has been suggested to result in an adverse impact on neurobehavioral development.3-6

The Tucson Children’s Assessment of Sleep Apnea (TuCASA) study is a prospective cohort study aimed at assessing the objective prevalence of SDB in preadolescent children aged 6 to 12 years using polysomnography (PSG). Although some studies have evaluated the presence of symptoms and correlates of SDB in Caucasian and African American children,7 TuCASA is the first one to study a large population of Hispanic children. Further, the study has investigated the symptoms, anatomic or physiologic correlates, and consequences of SDB, including neuropsychologic performance, in children. This article examines the methodologic procedures and the cross-sectional outcome data from this study.

STUDY DESIGN

Participants

The study design for TuCASA has been described in detail previously.8 Five hundred three 6- to 12-year-old Caucasian and Hispanic children were recruited from selected elementary schools in the Tucson Unified School District to undergo unattended home PSG. Incentives were offered to schools to encourage participation. The selected schools were prescreened to ensure that between 25% and 75% of their children were of Hispanic descent. The children were asked to take home a short screening questionnaire with sleep, anthropometric, and demographic items. Parents were requested to complete the questionnaire, return it to the investigators, and indicate whether they would allow study personnel to call them. The screening questionnaire consisted of a one-page survey designed to assess the severity of

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obstructive sleep apnea syndrome (OSAS)-related symptoms in children. Questions such as “How often does your child snore loudly?,” “Is your child sleepy during the daytime?,” “Does your child stop breathing during sleep?,” and “Does your child have learning problems?” were evaluated by a parent on the scale of never, rarely, occasionally, frequently, almost always, or don’t know. A total of 7055 questionnaires were distributed, with a 33% return rate. Of the children for whom the surveys were returned, 45.4% were Hispanic and 38% were Caucasian. Of those returning questionnaires, 1219 (52.4%) supplied recruitment information, and from this group, 503 children were selected to undergo unattended home PSG. Children who had chronic medical conditions and attention deficit hyperactivity disorder (ADHD) were excluded. A full unattended PSG was performed at the home within 1 month of recruitment and another visit was scheduled at the medical center for neurocognitive evaluation several weeks later.

**Home Polysomnography**

A two-person, mixed-gender team arrived at the participant’s home approximately 1 hour before the child’s regular bedtime to prepare the child for an unattended PSG using a portable monitor capable of recording a full PSG montage. Use of this system in TuCASA has been described in detail elsewhere. Briefly, sensors included C3/A2 and C4/A1 electroencephalogram, right and left electro-oculogram, a bipolar submental electromyogram, thoracic and abdominal displacement (inductive plethysmography bands), airflow (nasal/oral thermistor), nasal pressure cannula, oximetry, ECG (single bipolar lead), snoring (microphone attached to the vest), body position (Hg gauge sensor), and ambient light (sensor attached to the vest to record on/off). The thermistor and nasal pressure signals were collected simultaneously by taping a nasal/oral thermistor on the superior surface of a nasal cannula. The data from the PSG were stored in real time on a 40-MB Personal Computer Memory Card International Association (PCMCIA) flashcard and reviewed in the morning. If the study had insufficient duration or quality of artifact-free signal, fewer than 4 hours of oximetry, or equipment malfunction, it was categorized as a failed study. A study was classified as “good” if a minimum of 5 or more hours of signal were scorable on at least two respiratory channels (airflow, thoracic or abdominal bands), oximetry, and one electroencephalogram signal. If 4 to 5 hours of scorable signal were present on at least one electroencephalogram, oximeter, and respiratory signal, the study was classified as “fair.” If an initial study failed, the subject was asked to have another sleep recording. The final overall “pass rate” of the studies was 97%.

Sleep was manually staged according to Rechtschaffen and Kales criteria. Arousals were identified using criteria published by the American Academy of Sleep Medicine. Obstructive apneas were identified if the magnitude of any ventilation signal decreased to below 25% of the baseline amplitude for at least 6 seconds or for two or more consecutive breaths. Hypopneas were scored if the magnitude of any ventilation signal decreased to below approximately 70% of the baseline amplitude for at least 6 seconds or for two or more consecutive breaths. Central apneas were scored if airflow and thoracoabdominal effort were absent. To describe a respiratory disturbance index (RDI) defined by different magnitudes of oxygen desaturation or arousal, software linked various levels of minimum oxygen desaturation or the presence of arousal to each scored apneic or hypopneic event. In this way, an RDI could be generated characterized by no oxygen desaturation (RDI0) or by 2% (RDI2%), 3% (RDI3%), or an arousal (RDI-A).

To assess the reliability of scoring, 5% of studies were rescored by the same scorer on a blinded basis. No significant difference was found between initial and repeat scoring. The two sets of studies showed good agreement regarding classification as sleep apnea (RDI0<1 or ≥1, k = 0.78). A night-to-night variability study in 10 children showed no statistically significant differences in key sleep parameters between two different nights of recording.

During the home visit, a visual oropharynx inspection was done, anthropometric measurements, seated blood pressure (BP), and a digital photograph of the oropharynx and tonsils were taken, and a more extensive sleep habits questionnaire was completed, in addition to PSG. A poststudy survey was completed by the caregiver the morning after the PSG.

**Behavioral Evaluation**

Behavior problems were measured using the Conners’ Parent Rating Scale–Revised (CPRS-R) long version (L) and the Child Behavior Checklist (CBCL). Families were paid $25 for completing the behavioral evaluation. The long version of CPRS-R contains 80 items. It is typically used with parents or caregivers when comprehensive information and *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition) (DSM-IV) consideration are required. Scales include oppositional, cognitive problems,
inattention, hyperactivity, anxious-shy, perfectionism, social problems, psychosomatic, Conners’ Global Index (restless impulsive, emotional lability), DSM-IV symptom subscales (inattentive, hyperactive impulsive), and ADHD index. Parents rate their children’s behavior in the past month on a four-point Likert scale (not true at all; just a little true; pretty much true; very much true). Subscale T scores can be calculated based on a large age- and gender-specific normative sample. A T score (mean 50, standard deviation [SD] 10) higher than 65 is considered to indicate moderate-to-severe clinical impairment. The CBCL was designed to assess social competence and behavior problems in children aged 4 to 18. It includes 118 items related to behavior problems, which are scored on a three-point scale (not true, somewhat true, or very/often true).

**Neurocognitive Evaluation**

A neurocognitive assessment was performed a mean of 38 days after the successful completion of the PSG. The 3-hour assessment battery consisted of a series of standardized neurocognitive measures completed in a fixed order and ending with a single standard 10-minute visual psychomotor vigilance task (PVT) trial. The cognitive measures administered to the children were completed as follows: the Wechsler Abbreviated Scale of Intelligence (WASI); letter–word identification, applied problems, and dictation from the Woodcock-Johnson Psycho-Educational Battery–Revised Tests of Achievement (WJ–R); and the Children’s Auditory Verbal Learning Test–2. Dependent measures from each of these tests are age-based standard scores that have a mean of 100 and SD of 15, and higher scores indicate better performance. The WASI is a brief and reliable measure of intelligence and was used to facilitate characterization of the study participants. Measures of full-scale intelligence quotient (IQ), verbal IQ, and performance IQ were obtained. The WJ–R was used to measure academic achievement measures were used to assess learning of, and memory for, information learned before and outside of the evaluation setting. Letter–word identification assesses letter and single word reading. Applied problems assesses math skills. Dictation is a measure of spelling, punctuation, grammar, and word usage. The Children’s Auditory Verbal Learning Test–2 was used to measure auditory verbal learning and memory abilities. This multi-trial word list learning task provides age-based standard scores for each of the following: five list learning trials, overall learning across trials (level of learning), recall of a second word list (interference trial) presented after the learning trials, and immediate and delayed recall of the original list. Attention was evaluated using the CPRS-R (L) questionnaire. The PVT-192 was used for the psychomotor vigilance testing. It is a simple task administered on a handheld device. Participants were asked to press a button as quickly as possible each time they saw a visual stimulus appear (a small red light-emitting diode–digital counter). The stimulus was presented approximately 100 times during the 10-minute task, with the interstimulus interval varying randomly from 2 to 10 seconds.

**Baseline Characteristics of the Tucson Children’s Assessment of Sleep Apnea Cohort**

Five hundred three children underwent PSG in the TuCASA study. The baseline characteristics of this sample are shown in Table 1. Forty-nine percent of the children were Hispanic and half the subjects were girls. The mean body mass index (BMI) was

<table>
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<td>165</td>
<td>184</td>
<td>154</td>
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<td>Neck circumference, cm (mean ± SD)</td>
<td>27 ± 3</td>
<td>26 ± 3</td>
<td>27 ± 4</td>
<td>29 ± 3</td>
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**Abbreviations:** BMI, body mass index; SD, standard deviation.
18.0 kg/m² (SD 4.4) and 10.4% had a BMI greater than the 95th percentile for their age, sex, and ethnicity and were classified as “obese.” Of the 503 PSGs, 480 were found to be of good quality and were used for further analyses. The average total time in bed was 542.7 ± 85.7 minutes, sleep latency was 18.5 ± 21.0 minutes, and total sleep time was 487.0 ± 79.7 minutes, with the average sleep efficiency being 89.8%.

These values were not significantly different in boys and girls.

**SLEEP-DISORDERED BREATHING**

**Prevalence and Predictors of Sleep-Disordered Breathing**

The primary goal of the TuCASA study was to determine the prevalence and correlates of SDB. The children were diagnosed as having SDB if the RDI3% was greater than or equal to one per hour of total sleep time. Composite variables were created based on a combination of selected survey items from the basic screening questionnaire and the more extensive sleep-habits questionnaire to elucidate the clinical correlates of SDB.19

The children were classified as snorers if parents reported that their child snored loudly “frequently” or “almost always.” Witnessed apnea was defined by the parents’ positive reply to the following items on the questionnaire: their child stopped or struggled to breathe, their child’s lips turned blue, or they shook their child because they were worried about their child’s breathing during sleep “frequently” or “almost always.” Subjects were diagnosed as having excessive daytime sleepiness (EDS) if the parents answered “frequently” or “almost always” on any of the following: their child was sleepy in the daytime, fell asleep while watching TV or in school, or had problems with falling asleep during the day. Insomnia was diagnosed if the parents reported that their child had trouble falling or staying asleep, did not have enough sleep, or was troubled by waking up too early and not being able to get back to sleep. Learning problems were considered present if the parent reported that the child had a problem with learning frequently or almost always.

Of the children undergoing PSG, 15% had snoring, 5.2% had witnessed apnea, 16.3% had EDS, 29.4% had insomnia, and 5.8% had learning problems.8 PSG evidence of SDB (RDI3% ≥ 1) was present in 24% of children (mean RDI3% 2.6 ± 3.4). The mean RDI3% in children who did not have SDB was 0.38 ± 0.28. The likelihood of SDB was higher in boys than in girls (odds ratio [OR] 1.9, CI 1.2–3.0, $P = .006$). Snoring (OR 3.5, CI 2.0–6.2, $P = .001$) and EDS (OR 2.1, CI 1.2–3.8, $P = .01$) were also significantly associated with SDB. Furthermore, learning problems, as reported by parents, were more common in children who had SDB than in those who did not have SDB (11.3% versus 4.1%, $P = .004$). However, reported witnessed apneas (OR 1.8, CI 0.8–4.3, $P = .15$) or insomnia (OR 0.9, CI 0.6–1.5, $P = .85$) were not associated with a higher likelihood of SDB. In addition, ethnicity (Hispanic or Caucasian), age, obesity, and airway size were not significantly different between children who did or did not have SDB.

Analyses were performed to assess the sensitivity, specificity, and likelihood ratios of different predictors for SDB.8 The sensitivity of different variables for identifying SDB was usually low, with highest being that of male sex (60%). Frequent loud snoring, EDS, and learning problems had low sensitivities of 29.5%, 24.4%, and 11.3%, respectively. The sensitivities continued to be low when combinations of different symptoms or demographic variables were assessed. However, the specificities of learning problems (95.9%), snoring (89.5%), and EDS (86.3%) for SDB were high. Similarly, the combinations of snoring and learning problems (98.9%), snoring and EDS (97.0%), and snoring and male gender (95.1%) had high specificities for SDB.

These findings should be useful in the clinical evaluation of children who have possible SDB. They suggest that although many children who have SDB will not have habitual snoring and EDS, when the symptoms are present, a diagnosis of SDB should be sought. Positive likelihood ratios for snoring (2.8) and learning problems (2.8) again suggest an increase in the chance of SDB being present when these are present. The results of the study also add to the current literature suggesting SDB as a possible contributing factor to poor academic achievement in children.

One limitation of the TuCASA study is the use of only a thermistor to monitor airflow. Because an end-tidal carbon dioxide (CO₂) monitor was not used, it is possible that some cases of obstructive hypoventilation may have been missed. Moreover, use of a nasal pressure transducer to identify hypopneas during PSG is now considered standard practice.20 Because most TuCASA analyses used thermistor-derived recordings, the presence and severity of SDB may be underestimated. Indeed, a comparison of nasal pressure transducer and thermistor in a sample from the TuCASA cohort suggested that the former was able to detect a significantly higher number of events than the latter.21 However, the nasal pressure transducer showed a greater likelihood of signal loss than the thermistor, which may make use of the former unfeasible in young children.

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Sleep-Disordered Breathing and Learning

Kaemingk and colleagues\(^{14}\) assessed the relationship between intelligence, learning, and memory, and academic achievement and SDB in TuCASA subjects. A group of children who had an RDI of greater than or equal to five (n = 77) was compared with a group who had an RDI of less than five (n = 72). A significant inverse relationship was evident between RDI and full IQ, performance IQ, immediate recall, and applied problems. Learning and memory were decreased in the group of otherwise healthy children who had a RDI of five or more. These results suggest that SDB has an important adverse impact on the ability to learn during childhood. Whether such impairment has lasting consequences will not be known until long-term follow-up of these children is completed.

Sleep-Disordered Breathing and Hypertension

Strong evidence implicates SDB as a risk factor for hypertension in adults.\(^{22,23}\) However, the data assessing such an association in children have been meager. In TuCASA, BP measurements were performed on children during the home visit for PSG recording. BP was measured in triplicate from the right arm of the child using a portable mercury sphygmomanometer and standardized techniques.\(^{24}\) The appropriate BP cuff was selected according to the measured arm circumference. In an analysis of the first 239 TuCASA study participants who completed unattended home PSGs, the association between hypertension and SDB was examined.\(^{25}\) Boys constituted 55% of this sample and 51% of the children were Hispanic. The mean age was 8.7 years, the BMI was 18.2 kg/m\(^2\), and the mean neck size was 27 cm. Obesity was defined as a BMI of greater than the 95th percentile standardized for age, sex, and ethnicity\(^{26}\) and 12% of the children were obese by this criterion.

The mean ± SD systolic and diastolic BPs were 98.4 ± 10.6 mm Hg and 62.0 ± 8.9 mm Hg, respectively. BP elevation was systolic and diastolic BP was above the 90th percentile when adjusted for age, height, and sex.\(^{27}\) Fifteen children (6%) had hypertension. Associations were noted between systolic and diastolic BP elevation and RDI defined by either 2%, 3%, or 4% oxygen desaturations linked with apneic and hypopneic events. However, BP elevation was not noted in children who had apneic/hypopneic events unassociated with oxygen desaturation. Obesity, poorer sleep efficiency, arousal index, and RD12% were independently associated with diastolic BP elevation. Habitual loud snoring, witnessed apnea, RDI2%, and poorer sleep efficiency were associated with systolic BP elevation. Sex, ethnicity, total sleep time, and parental smoking were not associated with either systolic or diastolic hypertension.

This study provides evidence for the association between poor sleep and SDB and hypertension in children. The results were in accordance with a prior study that reported higher BP in children who had OSA compared with those with primary snoring.\(^{28}\) That BP was not elevated in the absence of oxygen desaturation suggests hypoxemia to be a major factor in the cause of SDB-related hypertension. This finding is consistent with data in adults suggesting that hypoxic stress may be the pivotal factor contributing to endothelial dysfunction, hypertension, and SDB.\(^{29}\) Furthermore, obesity was associated with hypertension, suggesting that controlling obesity may help limit such adverse consequences.

Sleep-Disordered Breathing and Behavioral Problems

The correlation between SDB and behavioral problems was analyzed in one TuCASA study.\(^{30}\) The mean RDI for the sample evaluated in this study was 5.29 (SD 4.80, range 0.10–72.4). Children in the upper 15% of the RDI distribution had higher mean CBCL scores on the aggressive, attention problems, social problems, thought problems, total and externalizing scales. Hyperactivity, however, was not strongly associated with a higher RDI. Similarly, on the CPRS-R, high ORs for oppositional, cognitive problems, social problems, psychosomatic problems, ADHD index, and DSM total scales were seen in children in the upper 15% of the RDI distribution. Other data from TuCASA indicate that snoring children also have a higher prevalence of behavioral problems (Fig. 1). These results indicate that SDB is associated with increased behavioral morbidity in children who have SDB. Furthermore, they are consistent with clinical observations that behavioral problems are frequently the primary or initial manifestation of SDB in children.

Parasomnias and Sleep-Disordered Breathing

Parasomnias in children have been associated with sleep disruption, SDB, psychiatric comorbidities, and distress to the child and the family members.\(^{31–33}\) One TuCASA analysis characterized the relationship between parasomnias and SDB in these children. A sleep habits questionnaire administered on the night of PSG in this study included questions such as “Does this child sleepwalk?” and “Does this child talk in his or her
sleep? (Talk without being fully awake?)” and “How often does this child awaken at night afraid or appearing tearful?” The choices of responses were “never,” “less than three times per month,” “three to five times per month,” or “more than five times per month.” A child was classified as having parasomnias if sleepwalking was present more than three times per month, sleep talking was present more than five times per month or if the child had more than five fearful awakenings per month. Enuresis was defined as occurring more than five times per month.34

Of the children undergoing PSG, 3.5% had sleepwalking, 11.3% had sleep talking, 6.3% had fearful awakenings, and 7.5% had enuresis.8 Children with sleep talking were more likely to have concomitant sleepwalking and sleep terrors. However, arousal parasomnias and enuresis showed no association. Children with sleepwalking showed an increased prevalence of reported EDS, insomnia, and learning problems and a trend toward more habitual snoring.34 Children with sleep talking were more likely to have habitual snoring, insomnia, and learning problems, but not EDS. Children with fearful awakenings were more likely to have habitual snoring, EDS, insomnia, and learning problems. Enuresis was strongly associated with habitual snoring and witnessed apnea. As shown in Fig. 2, sleepwalking (OR 2.9, CI 1.1–7.8, P = .02) and sleep talking (OR 2.2, CI 1.2–4.1, P = .006) were associated with a higher likelihood of SDB. The data showed a nonsignificant trend for enuresis to be associated with SDB (OR 1.9, CI 0.9–3.9, P = .08). Fearful awakenings or child being fidgety were not associated with SDB.8

Parasomnias such as sleepwalking and sleep talking have traditionally been considered usual and inconsequential childhood occurrences. However, the TuCASA study demonstrated a greater likelihood of SDB and other sleep symptoms and learning problems among children who had parasomnias. Parasomnias may be a result of SDB and can improve with treatment of SDB.35 It remains to be elucidated whether the learning problems encountered in children who have parasomnias are a function of concomitant SDB or whether parasomnias are an independent risk factor for the learning difficulties.

Fig. 1. T Scores on the Conners’ Parent Rating Scales. Values are higher in snoring children.

Fig. 2. Associations between sleep-disordered breathing (SDB) and parasomnias. SDB was defined as an RD13% of more than one per hour of total sleep time. EN, enuresis; ST, sleep talking; SW, sleepwalking; TR, sleep terrors. (From Goodwin JL, Kaemingk KL, Fregosi RF, et al. Parasomnias and sleep disordered breathing in Caucasian and Hispanic children - the Tucson Children’s Assessment of Sleep Apnea study. BMC Med 2004;2:14; with permission. Available at: http://www.biomedcentral.com/1741-7015/2/14. Accessed June 23, 2008. Published online 2004 April 28. doi: 10.1186/1741-7015-2-14. Copyright © 2004 Goodwin et al; licensee BioMed Central Ltd. This is an Open Access article: verbatim copying and redistribution of this article are permitted in all media for any purpose, provided this notice is preserved along with the article’s original URL.)
Sleep-Disordered Breathing and Ventilatory Drive

Hypoxic and hypercapnic ventilatory drive in relation to the severity of SDB was examined in 50 children recruited from the TuCASA cohort. The investigators assessed ventilatory drive by measuring the mouth occlusion pressure response (pressure at 0.1 second [$P_{0.1}$]) in normoxia, at two levels of isocapnic hypoxia, and at three levels of hyperoxic hypercapnia. They found a significant correlation between resting pressure of end-tidal CO$_2$ ($P_{ET}$CO$_2$) with the obstructive apnea-hypopnea index (OAHI). The hypoxic, but not the hypercapnic, occlusion pressure response was significantly related to the OAHI (Fig. 3). These results suggest that CO$_2$ retention and reduced hypoxic ventilatory drive occur in children who have a high OAHI. CO$_2$ retention during wakefulness in children who have severe SDB may be consequent to perturbed central ventilatory control. Although mechanical obstruction from enlarged tonsils causing a narrowing of the pharyngeal airway may contribute to CO$_2$ retention, a study demonstrating failure of adenotonsillectomy to abolish resting CO$_2$ retention during wakefulness in children who had SDB argues against this being a primary mechanism. The reduced hypoxic responsiveness seen in children in the study may be a paraphenomenon of SDB or may predispose children to SDB.

Upper Airway Collapsibility in Sleep-Disordered Breathing

Children who have severe obstructive sleep apnea have a more collapsible pharynx than those of normal children. Seventeen children from the TuCASA cohort underwent testing to assess whether children who have mild SDB composed primarily of hypopneas rather than apneas also have more collapsible airways than normal children. Airway collapsibility was estimated in 7 children who had mild SDB (11.5 ± 0.1 hypopneas/h) and 10 age-matched controls (1.9 ± 0.2 hypopneas/h) during stable, non-rapid eye movement sleep. The groups were similar in regards to BMI, neck circumference, and estimated airway size. The intermittent Pcrit method (brief [two-breath] duration and sudden reductions in pharyngeal pressure by connecting the breathing mask to a negative pressure source) revealed more collapsible airways in children in the SDB group than in the age-matched controls. These observations point to an intrinsic abnormality in the pharyngeal airway of children who have even mild SDB that may predispose to this disorder.

Sleep-Disordered Breathing and Oropharyngeal Volume

Whether childhood OSA is associated with a smaller airway was evaluated in another analysis in the TuCASA cohort. MRIs of the pharynx were obtained in 18 awake children 7 to 12 years of age, with OAHI values ranging from 1.81 to 24.2 events/h, to assess the correlation between pharyngeal geometry and soft tissue anatomy and the severity of SDB. The investigators found...
a positive correlation between the OAHI and the size of tonsils ($r^2 = 0.42, P = .024$) and soft palate (proportion of variance of the dependent variable explained ($r^2 = 0.33, P = .049$) and an inverse correlation between the OAHI and the oropharyngeal volume ($r^2 = 0.42, P = .038$) and the retropalatal air space (ratio of the retropalatal airway cross-section area to the cross-section area of the soft palate, $r^2 = 0.49, P = .001$). As shown in Fig. 4, the oropharyngeal volume and the narrowest anterior-posterior oropharyngeal diameter were reduced in the high OAHI group. The high OAHI group had a narrower retropalatal airway where the adenoids, tonsils, and soft palate overlap than the low-OAHI group. The narrow upper airway likely contributes to worse SDB in children who have a high OAHI.

**PSYCHOMOTOR VIGILANCE TASK PERFORMANCE**

Although the PVT is commonly used as a marker of vigilance in adults, no normative data in children exist. In a TuCASA analysis by Venker and colleagues, normal PVT performance values were derived by analyzing data from a subsample composed of children who had an RDI $\geq$ 3% less than one and no parent-reported sleep problems ($n = 162$). Approximately $51\%$ of this subsample was female. The reaction time (RT) decreased with increasing age, with children 11 years of age ($n = 15$) having a mean RT of 396.3 milliseconds compared with 721.15 milliseconds in children 6 years of age ($n = 27$). Boys and girls had statistically significantly different median RT ($P<.001$). Boys had a shorter median RT (659.4 versus 787.6 ms) and fewer lapses (39.0 versus 58.2) than girls at age 6, but performance on both measures was approximately equal by age 11. The interaction between gender and age was also significant. For boys, mean reciprocal RT calculated because the distribution of mean RT was positively skewed) is expected to be 2.06 seconds$^{-1}$ at age 6, and is expected to increase by 0.191 seconds$^{-1}$ with each additional year of age. For girls, mean reciprocal RT is expected to be 1.61 seconds$^{-1}$ at age 6, and is expected to increase by 0.274 seconds$^{-1}$ with each additional year of age. The results were not different in Hispanic or Caucasian participants. The median number of total errors was lower for girls than for boys (four versus nine). This improvement in performance among school-aged children is consistent with the neurocognitive and physiologic development taking place during these years.

**BEHAVIORAL PROBLEMS ASSOCIATED WITH OVERWEIGHT**

Of the 480 sleep studies completed in TuCASA, 402 (83.7%) had complete anthropometric and behavioral data available and constituted the sample for a study assessing the relationships among obesity, SDB, and behavioral problems. Fifty-nine out of these 402 children (~15%) were classified as overweight (at or above the 95th percentile for their age and gender group). The children in the overweight group were slightly older (9.2 versus 8.7 years, $P = .04$) and more likely to be Hispanic (55.9% versus 35.6%, $P<.01$) compared with the non-overweight group. No significant differences existed in gender, RDI, or parent education between the two groups. Overweight children were more likely to be classified in the clinical range for psychosomatic complaints (OR 2.15, CI 1.02–4.54) on the CPRS-R. The Conners’ psychosomatic complaints scale includes items related to headaches, stomach aches in general, stomach aches before school, vague complaints that are not supported by physical illness, and fatigue. However, this difference was not significant when adjusted for SDB.

Overweight children also had a higher probability of being classified within the clinical range for internalizing symptoms (OR 2.23, CI 1.05–4.72), withdrawal (OR 4.69, CI 2.05–10.73), and social problems (OR 3.18, CI 1.53–6.60) on the CBCL. When adjusted for SDB, the probability of clinically relevant withdrawal (OR 3.83, CI 1.59–9.22) and social problems (OR 2.49, CI 1.14–5.44) remained significantly higher for overweight subjects. The
CBCL withdrawn scale includes items related to inhibition and withdrawal and predicts anxiety and depression.\textsuperscript{42} Social scale items are related to social incompetence and being teased and disliked by peers. Overweight children may be bullied and teased by their peers because of their weight, whereas withdrawal may be a secondary to self-conscious behavior or judgment by peers.

**SUMMARY**

TuCASA is a prospective cohort study of children aged 6 to 12 years that has helped elucidate anatomic and physiologic correlates of SDB and associated clinical outcomes in this age group. The analyses from this epidemiologic study suggest that obesity and SDB are associated with increased behavioral morbidity. Parasomnias, erstwhile considered benign occurrences in children, were shown to be associated with SDB. Furthermore, learning was impaired in children who had PSG-documented SDB. Anatomic and physiologic substudies revealed that children who have SDB have smaller upper airways, increased tonsillar and palatal soft tissue volume, and more collapsible upper airways. Furthermore, SDB may be associated with increased $P_{ET}CO_2$ and depressed hypoxic responsiveness. In the future, results from a 4-year follow-up of the TuCASA cohort will be available, which should result in further information concerning the potential impact of SDB on childhood learning, development, and physiology.

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