

Original article

Sleep architecture in normal Caucasian and Hispanic children aged 6–11 years recorded during unattended home polysomnography: experience from the Tucson Children's Assessment of Sleep Apnea Study (TuCASA)

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Abstract

Objective: To obtain normative sleep architecture data from unattended home polysomnography in Caucasian and Hispanic children aged 6–11 years.

Design and subjects: Unattended home polysomnography was performed on a single night in Caucasian and Hispanic children aged 6–11 years as part of the Tucson Children's Assessment of Sleep Apnea Study (TuCASA), a cohort study designed to examine the prevalence and correlates of sleep disordered breathing. A subset of 42 children enrolled in TuCASA who had no symptoms of any sleep disorder and had polysomnograms without technical recording problems.

Results: Sleep architecture in preadolescent Caucasian and Hispanic children was not different between boys and girls. However, total sleep time (TST), sleep efficiency (SLE) and time spent in REM sleep declined with increasing age. In addition, the number of sleep to wake stage shifts was slightly higher in younger children. Hispanic children had less Stage 3/4 sleep (18 ± 1 vs. $22 \pm 1\%$, $P \leq 0.02$) and correspondingly more Stage 2 sleep (55 ± 2 vs. $50.0 \pm 1\%$, $P \leq 0.02$) than their Caucasian counterparts.

Conclusions: Using unattended home polysomnography, indices of sleep duration and architecture are not different between preadolescent boys and girls. However, with increasing age, TST and SLE decreased. In addition, there are differences in sleep architecture between Caucasians and Hispanics, which may be an important consideration in the evaluation of children with sleep disorders.

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1. Introduction

The quality and amount of sleep is increasingly recognized as an important factor in childhood development [1]. Chronically poor sleep adversely impacts school performance and behavior [2]. In addition, sleep disruption caused by sleep disordered breathing (SDB) and periodic limb movements (PLMS) appear to be associated with hyperactive behavior and difficulty with learning [3,4].

Accurate assessment of sleep in children often is difficult. It frequently is determined by using questionnaires [2,5,6]. However, questionnaire data may be inaccurate if subjective perception of sleep does not correspond to objective indices. This can be particularly true in young children for whom a parent or guardian completes the survey [7]. Actigraphy is sometimes used to obtain better estimates of quality and quantity of sleep, but it does not provide any information pertaining to sleep staging and can overestimate the amount of sleep if an individual lies quietly in bed [8]. Therefore, polysomnography is considered the 'gold standard' by which data pertaining to sleep quality and quantity can be objectively determined. Most studies reporting normative

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sleep data in children have been performed in a sleep laboratory with a technician in attendance [9–14]. However, sleep data obtained in a laboratory setting sometimes do not correspond to information recorded from a home environment. Sleep may be particularly disrupted on the first night in a laboratory, the so-called ‘first night effect’ [11,15]. Some studies have suggested that unattended polysomnography performed in the home minimizes ‘first night effect’ [16,17]. Because young children are less compliant than older children or adults, experience using unattended polysomnography in this age group is limited [16,17]. In addition, these unattended studies have not assessed ventilation or possible ethnic differences [16,17].

The Tucson Children’s Assessment of Sleep Apnea Study (TuCASA) is a longitudinal cohort study of preadolescent children designed to study the physiologic and neurocognitive correlates of SDB. Because TuCASA participants were recruited from the general population, and all had unattended home polysomnography, it provides an opportune means to obtain normative sleep architecture data from Caucasian and Hispanic children aged 6–11 years.

2. Methods

2.1. Subjects

Forty-two subjects of a total of 331 children who had a one night unattended home polysomnogram performed as part of the ongoing TuCASA were selected for this study. Begun in 1999, TuCASA is a cohort study examining the prevalence and correlates of SDB in Caucasian and Hispanic children aged 6 through 11 years. Subjects were recruited from selected schools in the Tucson Unified School District (TUSD), a large district with a population representative of children living in Southern Arizona. To assure that an adequate mix of Caucasian and Hispanic children were recruited, elementary school populations were pre-screened so that at least 25% but no more than 75% of children attending the school were of self-reported Hispanic ethnicity. The University of Arizona Human Subjects Committee and the TUSD Research Committee approved the TuCASA study.

Parents of children in participating schools were asked to complete a 13 item screening questionnaire inquiring about symptoms which could be attributable to SDB. Subjects were recruited for polysomnography by contacting parents who returned questionnaires and indicated willingness for their child to participate in the study. At the time of recruitment, the presence of chronic medical problems was ascertained and those children who had tonsillectomies, or who were diagnosed with asthma or other respiratory disorders, mental retardation, learning disorders, attention deficit disorder, and other major medical conditions were excluded from having a polysomnogram performed. On the night of the polysomnogram, parents completed a questionnaire with

items pertaining to sleep habits and sleep symptoms; additional information included measurements of height and weight. A survey administered on the morning after the polysomnogram assessed how representative the study night was in comparison to the child’s usual sleep. Integral to the TuCASA protocol was a battery of neurocognitive tests that each child performed on a subsequent day. As part of this testing, the level of parental education was ascertained as the number of years of schooling of the parent accompanying the child to the testing site.

Based on their screening, sleep habits and morning questionnaires, subjects were excluded from the present analysis if they had symptoms of insomnia, excessive daytime sleepiness, snoring and episodes of witnessed apnea at night, and if subjective sleep quality on the night of their study was ‘much worse than usual’. Items from the screening, sleep habits and morning questionnaires used to exclude participants from this analysis are shown in Appendix A. Items in these questionnaires have been adapted from other studies of sleep in children [5,18].

Subjects were selected for the study if their polysomnograms met the following criteria:

- Problems encountered in the scoring of sleep stages such as periods of uninterpretable EEG, EOG and chin EMG represented <10% of the recording.
- The entire sleep period time was captured thus excluding cases where sleep onset occurred before data acquisition started or data acquisition stopped before final awakening.
- It was possible to determine when ambient light decreased (signaling when the subject went to bed) thus excluding cases with a poor lights on/off signal.
- The respiratory disturbance index (RDI) was less than five events per hour of total sleep time (vide infra).

2.2. Polysomnography

A home polysomnogram was scheduled as soon as possible after recruitment. The procedures used in obtaining and scoring polysomnographic data have previously been described [19]. Briefly, unattended home polysomnograms were obtained using the Compumedics PS-2 system (Abbotsford, Victoria, Australia). The following signals were obtained: C₃/A₂ and C₄/A₁ EEG, right and left electrooculogram, a bipolar submental electromyogram, thoracic and abdominal displacement (inductive plethysmography bands), airflow (nasal/oral thermocouple), nasal pressure cannula, electrocardiogram (single bipolar lead), snoring (microphone attached to a vest), body position (Hg gauge sensor), and ambient light (sensor attached to the vest to record on/off). Polysomnograms were processed by a single scorer using Compumedics W-Series Replay, v 2.0, release 22. Sleep stages were scored by a single registered polysomnographic technologist using standard criteria [20]. The

Table 1
Sleep architecture data in three age groups of preadolescent children

Age group (n)	6–7 years (10)		8–9 years (19)		10–11 years (13)	
	Mean	SE	Mean	SE	Mean	SE
Sleep period time (SPT)	605	14	580	10	587	15
Total sleep time (TST) ^a	555	12	528	10	507	16
Sleep latency (minutes)	12	4	16	3	24	8
Sleep efficiency (SLE, %) ^b	92	1	91	1	87	2
Number of arousals	35	3	27	2	35	5
Arousals per hour of TST	4	1	3	1	4	1
Number of stage shifts						
Sleep to wake ^c	8	2	6	1	5	1
Stage 1 sleep						
Minutes	29	3	27	4	29	7
%	5	1	5	1	6	2
Stage 2 sleep						
Minutes	274	9	281	10	265	14
%	49	1	53	2	52	2
Stage 3/4 sleep						
Minutes	116	9	103	7	102	6
%	21	2	20	1	20	1
REM sleep						
Minutes ^d	138	5	118	7	112	7
%	25	1	22	1	22	1
REM latency (minutes)	128	10	134	11	127	9

^a Progressive decline with age, $P \leq 0.02$.

^b Progressive decline with age, $P \leq 0.03$.

^c Progressive decline with age $P = 0.06$.

^d Progressive decline with age $P \leq 0.05$.

scoring technologist was blinded to the participant's age, ethnicity and gender. In addition, for the purposes of quality assurance and consistency in scoring, one of the investigators periodically reviewed application of the scoring rules with the technologist and 5% were blindly rescored. No trends or inconsistencies were identified [19]. Arousals were identified using American Sleep Disorders Association criteria [21]. The RDI was defined as the number of respiratory events (apneas and hypopneas) per hour of the total sleep time. Apneas were scored if the peak to trough amplitude of the airflow signal using the thermistor decreased below at least 25% of the amplitude of 'baseline' breathing and if this change lasted for >6 s or two breath cycles. Hypopneas were scored if the amplitude of any ventilation signal decreased below approximately 70% of the 'baseline' amplitude.

2.3. Definitions and data analysis

The sleep period time (SPT) was defined as the time from 'lights off' to final awakening and total sleep time (TST) was the total amount of recorded sleep during the polysomnogram. Sleep efficiency (SLE) was calculated as TST/SPT. Percent time in each sleep stage was calculated based on the TST. The arousal index (ArI) was defined as the number of arousals per hour of TST. Obesity was considered as being present if the body mass index was in the upper 5th percen-

tile of appropriate age/gender/ethnicity normative values [22].

Comparisons among ethnic groups, gender and age were performed using unpaired *t*-tests and analysis of variance. Pearson correlation coefficients were calculated to determine if there were any associations between continuous variables. Analyses were performed using SPSS version 10.1 for Windows.

3. Results

No differences were found with respect to any parameter of sleep architecture between genders. Thus, data for both genders were combined, and stratified by ethnicity (Caucasian and Hispanic) and age (2 year increments).

As shown in Table 1, TST declined in a progressive manner with age, decreasing from 555 ± 12 min (mean \pm SE) in 6–7 year olds to 507 ± 16 min in 10–11 year olds ($P \leq 0.02$). However, SPT remained constant. Consequently, SLE also declined with age from 92 ± 1 in 6–7 year olds to 87 ± 2 in 10–11 year olds ($P \leq 0.03$). The decrease in SLE appears to coincide with an increase in sleep latency with age (12 ± 4 min in 6–7 year olds vs. 24 ± 10 min in 10–11 year olds) although these changes did not reach statistical significance ($P = 0.16$). These observations are consistent with a negative correlation between increasing age, and both TST ($r = -0.38$,

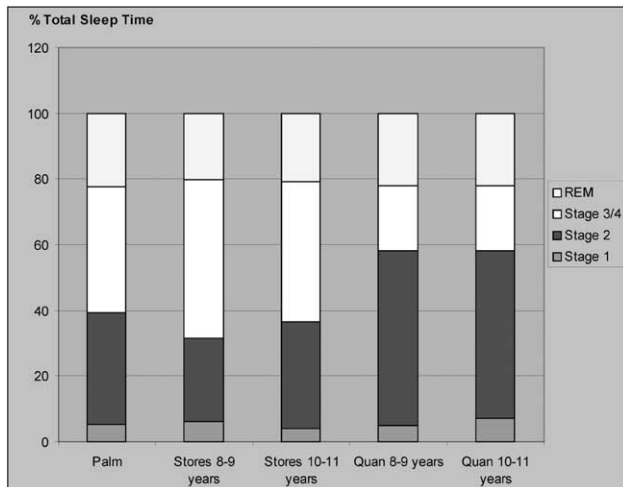


Fig. 1. Comparison of sleep architecture in the present study (Quan et al.) at ages 8–9 years ($n = 19$) and 10–11 years ($n = 13$) with Palm et al. [16] at ages 8–12 years ($n = 18$) and Stores et al. [17] at ages 8–9 years ($n = 14$) and 10–11 years ($n = 12$). Stacked bars represent mean values.

$P \leq 0.02$) and SLE ($r = -0.36$, $P = 0.02$). Sleep stage distribution did not change as a function of age except for a progressive decrease in the number of minutes spent in REM sleep from 138 ± 5 min in 6–7 year olds to 112 ± 7 min in 10–11 year olds ($P \leq 0.05$), although % time spent in REM did not show the same decline. The absolute number of arousals was not different among the three age groups. However, the number of stage shifts from sleep to wake was slightly higher in the 6–7 year old age group in comparison to older children ($P = 0.06$).

Caucasians ($n = 26$) and Hispanics ($n = 16$) differed in several sleep architecture parameters. Hispanics were noted to have slightly less minutes and % time spent in Stage 3/4 sleep (94 ± 6 vs. 113 ± 5 min, $P \leq 0.02$; 18 ± 1 vs. $22 \pm 1\%$, $P \leq 0.02$). Correspondingly, Stage 2 sleep was increased (290 ± 9 vs. 265 ± 9 min, $P = 0.07$; 55 ± 2 vs. $50.0 \pm 1\%$, $P = 0.02$). No other ethnic differences in sleep architecture were found. Because of the limited number of participants, stratification of these ethnic differences by age was not possible.

Obesity was noted in 12% of the sample. However, no differences in sleep architecture could be attributed to it.

In addition, although children with significant SDB were excluded ($RDI > 5$), correlations were performed to determine whether variation in this low range of RDI could explain the findings from this analysis. No effect of RDI on sleep architecture could be discerned.

Data indicating the level of parental education were available in 28 children and were used as a surrogate for socioeconomic status. Of the 14 children without such data, five were Caucasian and nine were Hispanic. Although there was a trend for parents of Caucasians to be slightly more educated than Hispanics (14.7 ± 0.4 vs. 13.3 ± 0.9 years, $P = 0.113$), there was no effect of parental education on sleep architecture. Controlling for parental education in

analyses pertaining to differences between Hispanics and Caucasians also did not change the observed findings.

4. Discussion

In this study, we found that sleep architecture in preadolescent Caucasian and Hispanic children was not different between boys and girls. However, TST, SLE and time spent in REM sleep declined with increasing age. In addition, the number of stage shifts from sleep to wake was slightly higher in younger children. We also observed that Hispanic children had less Stage 3/4 sleep and correspondingly more Stage 2 sleep than their Caucasian counterparts.

No indices of sleep duration or architecture were different between boys and girls in our study. Several previous studies have also failed to report gender differences [14,16,17]. In contrast, others have found that boys had greater amounts of slow-wave sleep [11,12,23]. Unlike the current study which used unattended home polysomnography, these latter investigations were performed in a sleep laboratory. It is unclear, however, why the recording environment would impact any gender differences in sleep architecture. Nevertheless, despite a possible gender effect in the amount of slow-wave sleep, there appears to be little difference between boys and girls in overall sleep duration and architecture [11,12,16,17,23], a finding confirmed by the present study.

In comparison to the only other reports of normative sleep data obtained using unattended polysomnography [16,17], we found that children spent substantially less time in slow-wave sleep and more time in Stage 2 sleep (Fig. 1). Nevertheless, our data are consistent with sleep architecture data observed in several other studies performed in a sleep laboratory [9,11,13,23]. It has been previously suggested that these discrepancies in Stage 2 and slow-wave sleep are a result of an inherent, albeit unknown, difference between recording environments [17]. However, data from the current study would indicate otherwise.

Unlike the absence of a gender effect, we observed that increasing age was associated with a decrease in TST and SLE. The decline in TST with age in 6–11 year olds has been noted in other studies [12,17], but not in all [23]. However, unlike other studies which did not find any change in SLE with age [12,17], we noted that SLE declined. This occurred because SPT remained constant across all three age groups despite allowing participants to regulate their own bedtime and wake times. In other studies, SPT decreased in parallel with TST [12,17]. One possible explanation for this discrepancy may be differences in defining the recording start time across studies. The study by Coble et al. was performed in a sleep laboratory where ‘lights out’ and ‘lights on’ times were manually designated on the polysomnogram [12]. In the investigation by Stores et al., performed using unattended recordings in the home, documentation of the ‘lights out’ time was not given [17]. In our

study, an ambient light detector was used to define ‘lights out’ or when the child went to bed. However, it is possible that some children engaged in other activities in bed after the lights had been dimmed before attempting to sleep. If this was the case, sleep latency would be increased and SLE decreased. One might envision that older children might be more inclined to engage in such activity, thus explaining the low SLE in the 10–11 year olds in our study. Arguing for this hypothesis is our finding that there was a tendency for sleep latency to increase with age although statistical significance was not achieved.

In addition to age-related changes in TST and SLE, we noted a decrease in the amount of time spent in REM sleep with increasing age and a slightly higher number of sleep to wake stage shifts in younger children. In contrast, data reported by Coble et al. and Stores et al. indicate that % time spent in Stage 2 sleep increases and % time spent in slow-wave sleep decreases with age [12,17]. Williams et al. also noted that there were age-related increases in the number of stages and awakenings, but only in boys [23]. Furthermore, ArI and time spent in REM sleep remained constant in this age range [12,17,24]. The explanation for the differences in age-related changes in sleep architecture between these previous reports and our findings is not readily apparent, but it does not appear to be related to the recording environment.

A unique feature of this study is the comparison of polysomnography data between normal Caucasian and Hispanic children. We found that Hispanics had less slow-wave sleep and correspondingly more Stage 2 sleep. Several studies have reported ethnic differences in sleep complaints for both adults and children [25–27]. Hispanic adolescents have a greater risk of insomnia [25]. Nevertheless, studies which have compared sleep among ethnic groups, particularly Hispanics, using polysomnography are limited. One such study in normal adults found a higher REM density in Hispanics in comparison to Caucasians, African Americans and Asians [28]. Another study focusing on REM sleep in depressed adults did not find any differences between Caucasians and Hispanics [29]. No previous studies have compared polysomnographic sleep variables among ethnic groups in children. The explanation for the differences we observed between Caucasians and Hispanics is unclear. It is possible that socioeconomic differences reflected in the home recording environment are important contributing factors. Some of the Hispanic children spoke limited English and lived in poorer housing than their Caucasian counterparts. However, when parental education was used as a surrogate for socioeconomic status, there was no impact of this factor on sleep stage distribution or on the ethnic differences we observed. Further investigation of this hypothesis would require comparison with laboratory polysomnography and better characterization of the home recording environment. Nonetheless, recognizing that normative sleep data are different between Caucasian and Hispanic children when obtained using home unattended

recording may be important in subsequent studies of children with sleep disorders.

We acknowledge that it may be necessary to qualify some of our conclusions. First, some of our observations, such as the lower SLE, may have been influenced by a ‘first night effect’. However, Palm et al. have reported that the ‘first night effect’ is minimal with unattended polysomnography in children [16]. In addition, while the SLE noted in our study is lower than that reported in several studies [11,12,16,17], others have reported comparable values in children [9,13]. Second, because the primary reason for performing polysomnography was to detect SDB, children in our study wore several ventilation monitors that were not used in previous studies. These may have adversely impacted sleep as well. Third, we also recognize that a sample containing children with a RDI of up to five events per hour of TST may have included some with SDB. However, although an apnea index of >1 is thought to be abnormal in children [14], others have used RDI values between 3 and 5 as a threshold for SDB in children [9,10,30]. Moreover, recent preliminary data from TuCASA indicate that a RDI threshold of 5 identifies children with symptoms associated with sleep apnea [31]. Furthermore, within our sample, there was no relationship between RDI and any index of sleep architecture. Fourth, we did not measure PLMS during polysomnography because of the potential injury should a child become entangled in the wiring. Thus, an effect of PLMS on sleep architecture cannot be excluded [3]. Fifth, we did not perform Tanner staging to determine sexual maturity in our cohort. Therefore, we could not assess any changes in sleep related to differences in sexual development. Finally, given the limited number of participants without symptoms of a sleep disorder and who had polysomnograms that met the quality criteria for this analysis, we were not able to perform detailed stratified analyses to determine whether there were significant interactions between age, gender and ethnicity.

In conclusion, we found that indices of sleep duration and architecture were not different between preadolescent boys and girls with unattended home polysomnography. However, with increasing age, TST and SLE decreased. In addition, differences in sleep architecture were observed between Caucasians and Hispanics, which may be an important consideration in the evaluation of children with sleep disorders.

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Appendix A. Questions from the screening, sleep habits and morning questionnaires used to exclude participants from current analyses

A.1. Screening questionnaire

1. Does your child stop breathing during sleep?
2. Does your child struggle to breathe while asleep?
3. Do you ever shake your child during sleep to make him/her breathe again?
4. Do your child's lips ever turn blue or purple while he/she is sleeping?
5. How often does your child snore loudly?
6. Is your child sleepy during the daytime?
7. Does your child fall asleep at school?
8. Does your child fall asleep while watching television?

Possible answers to the above questions were 'Almost always', 'Frequently', 'Occasionally', 'Rarely', 'Never' and 'Don't know'.

Children were excluded if any of Questions 1–8 were answered more often than 'Occasionally'.

A.2. Sleep habits questionnaire

Has this child ever been troubled by any of the following sleep problems?

- a. Trouble falling asleep?
- b. Trouble staying asleep?
- c. Waking up too early and not being able to get back to sleep?
- d. Falling asleep during the day?

Possible answers to the above questions were 'Yes, has the problem', 'Yes, but no longer has the problem', and 'No, does not have the problem'.

Children were excluded if any of the questions were answered 'Yes, has the problem'.

A.3. Morning questionnaire

Compared to this child's usual night's sleep, how well did he/she sleep last night?

Possible answers to the above question were 'Much worse than usual', 'Somewhat worse than usual', 'As well as usual', 'A little bit better than usual', and 'Much better than usual'.

Children were excluded if the question was answered 'Much worse than usual'.

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