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# The relation between sleep disturbance and the size of the upper airway in children usint the acoustic pharyngometer/rhinome

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BOSTON UNIVERSITY  
HENRY M. GOLDMAN SCHOOL OF DENTAL MEDICINE

THESIS

**THE RELATION BETWEEN SLEEP DISTURBANCE AND THE SIZE OF THE UPPER  
AIRWAY IN CHILDREN USING THE ACOUSTIC  
PHARYNGOMETER/RHINOMETER**

by

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AIRWAY IN CHILDREN USING THE ACOUSTIC PHARYNGOMETER/RHINOMETER

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**ABSTRACT**

**Objective:** The objective of this study is to evaluate the relation between the size of the upper airway using the Acoustic Pharyngometry/Rhinometry and the sleep disorders in children.

**Methods:** Children between the ages 3-18 years with or without sleep disturbance who attended the Pediatric dental clinic and Orthodontic clinic at Henry M. Goldman School of Dental Medicine were evaluated to participate in the study. Based on BEARS questionnaires (sleep disturbance screening tool for pediatric patients) the participants were then divided to either the control or the case group. PSQ (pediatric sleep questionnaires) were used to evaluate the sleep pattern of the participating subjects. Subjects were then examined using the Eccovision Acoustic Pharyngometry (AP) and Acoustic Rhinometry (AR) (Hood Laboratories, Pembroke, MA) to obtain the airways measurements.

**Results:** Regression analysis of the Acoustic Pharyngometry measurements showed statistical significant differences in the Pharyngometry Minimum cross sectional area (PMCSA) between children with sleep disturbance and children without sleep disturbance after adjusting for gender, race and age ( $p=0.01$ ). The analysis of the Rhinometry volume (RV) showed statistical significant results between children with sleep disturbance and children without sleep

disturbance after adjusting for gender, race and age ( $p < 0.05$ ). Regression analysis of air resistance (RAR) showed statistical significant difference between children with sleep disturbance and children without sleep disturbance when controlling for gender, race and age ( $p = 0.03$ ).

**Conclusions:** RV and PMCSA were significantly lower in children with sleep disorder breathing (SDB) compared to children without SDB.

## TABLE OF CONTENTS

ABSTRACT.....	iv
TABLE OF CONTENTS.....	vi
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
INTRODUCTION.....	1
STUDY OBJECTIVES.....	5
METHODS.....	6
RESULTS.....	12
DISCUSSION.....	15
CONCLUSION.....	18
APPENDIX.....	19
BIBLIOGRAPHY.....	40
CURRICULUM VITAE.....	42

## LIST OF TABLES

Table 1. Mean of Demographic characteristics of case and control groups .....	23
Table 2. Univariate analysis describing differences in various Acoustic Pharyngometry measurements between cases and controls .....	25
Table 3. Univariate analysis describing differences in various Acoustic Rhinometry measurements between cases and controls .....	25
Table 4. Regression analyses models for the evaluation AP/AR measurements among cases and controls adjusting for age, gender and race .....	26
Table 5. <i>p</i> -values of Univariate analyses that evaluated the mean of PV among snoring, breathing patterns groups, overweight and passive smoking.....	26

## LIST OF FIGURES

Figure 1. Steps taken for the enrollment and measurements .....	28
Figure 2. Number of subjects enrolled in the study .....	29
Figure 3. Means of Acoustic Pharyngometer volume among controls and cases .....	30
Figure 4: Means of Acoustic Pharyngometer CSA among controls and cases.....	30
Figure 5: Comparing means of Rhinometry volume among controls and cases .....	31
Figure 6: Means of Rhinometry air resistance among controls and cases .....	31
Figure 7: An example of Acoustic Pharyngograph of a case with sleep disturbance.....	32
Figure 8: An example of Acoustic Rhinograph of a control without sleep disturbance.....	32

**LIST OF ABBREVIATIONS**

- AP ..... Acoustic Pharyngometer
- AR..... Acoustic Rhinometer

## INTRODUCTION

Sleep Disorder Breathing (SDB) is the elevation of the levels of resistance in the upper airway that could result in signs such as snoring, loud breathing and Obstructive Sleep Apnea Syndrome (OSAS) [1].

SDB can be defined as any obstruction in the upper airway either partial or complete; with or without snoring, loud breathing and sleepiness during daytime[2]. SDB has side effects on the health especially on the Cardiovascular and Cerebrovascular systems[2]. Elevate levels of Blood pressure is one of the negative impacts of SDB on the Cardiovascular system[2].

The early diagnosis of the SDB in children is very important to avoid any complications associated with it [1]. A study that evaluated the quality of life and depression level of children with signs of sleep disorders breathing (SDB) and snoring; has found that children with SDB and snoring had a lower quality of life and higher depression levels than children without SDB[7].

OSAS can affect the quality of life as well as other aspects of health[3]. OSAS is a syndrome that can be found among children. Untreated OSAS in children could affect the children's growth and development[4]. This includes behavioral disorders, attention and learning difficulties, delay in the growth and development, hyperactivity as well as pulmonary hypertension and increase in the blood pressure[4].

A technical report that studied the management of obstructive sleep apnea syndrome (OSAS) in children showed that the prevalence of OSAS was 1.2% to 5.7%[6]. It also stated that the prevalence of primary snoring was 1.5 to 27.6%[6].

Moreover, Beydon *et al* found that the prevalence is up to 1-4% among children at school age[3]. Another study showed an increased prevalence of sleep disorders and snoring episodes in children [7].

Observed sleep disturbance with pulmonary arousals are signs of the OSAS. Skeletal malformations, adenotonsillar hypertrophy, obesity and other metabolic and respiratory diseases are all possible causes of OSAS[3].

Baris *et al* study evaluated children with mean age  $101.85 \pm 59.15$  months; their results showed the prevalence of children with OSAS to be 33.6% [1].

In order to confirm the diagnosis of the OSAS, one sign of upper airway obstruction along with nocturnal symptoms should be presented[3]. The gold standard for the diagnosis of sleep disturbances is Polysomnography[3]. Obstructive sleep apnea can be diagnosed using it by an over night sleep study[8]. Partial obstruction of the upper airway along with reduction in the airflow, frequent arousals and Oxygen desaturation during sleep are the key points in the diagnosis of OSAS[8].

There are many factors that could affect the size of the upper airway; interestingly one of them is the missing primary or/and permanent teeth during the early years of life[9]. Obesity among children is another factor that affects the airway size and thus causes sleep disturbance[2, 6, 8].

However, there is no standard measurement of the size of the airway of children. The studies in the literature show little variation in the measurements of the airway for the same ages measured by the Acoustic Rhinometry (AR). The acoustic Pharyngometer (AP) and acoustic Rhinometer (AR) were used to get the airway measurements of the study subjects. The AR and AP produce sound pulses in a wave tube, which makes the acoustic signal. The reflected sound represents the geometry of the airway.

Riechelmann *et al*, gave a ranged of the cross sectional area of the airway of children between ages 3-6 years old measured by the AR to be  $0.29 \pm 0.06$  cm<sup>2</sup> at the distance

0.7cm[10]. This study showed no significant difference between male and female in children in the sizes of the airway[10].

Another study reported the volume of the airways of the children with age range between 3.8-13.1 years to be the following; 2.57 (2.49, 2.64) cm<sup>3</sup> at 0-4cm, 3.62 (3.50, 3.73)cm<sup>3</sup> at 0-5cm, 2.03 (1.95, 2.10) cm<sup>3</sup> at 1-4cm, 2.59 (2.49, 2.69) cm<sup>3</sup> at 2-5cm[11]. That study showed no association between Acoustic Rhinometry (AR) values and sex, atopy or hay fever. However, there was a decrease in the size of the airway in the children with wheezing or/and Asthma[11]. A study that evaluated children ages 9-11 years with Acoustic Rhinometry; found that the mean of the volume is 3.71 cm<sup>3</sup> (3.58-3.84) at 2-5cm[12].

A study that measured the airways of preschool children stated that using the volume of the airway measured by the Acoustic Rhinometry is more accurate than minimum cross sectional area (MCA) of the airway[13]. Results from different studies that used the acoustic Rhinometry showed variation in the measurements due to the difference in the measurement techniques, operator, software and equipment[14, 15].

A study by Heliberg *et al*, suggested few guidelines to help getting the most accurate results using the Acoustic Rhinometry[14]. The volume at the distance of 0-5cm into the nose and the minimum cross sectional areas are the most important measurements to evaluate in the graphs given by the Acoustic Rhinometry[14].

Acoustic Pharyngometer (AP) used to evaluate the pharyngeal volume before and after tonsillectomy in children. Results showed increase in the pharyngeal volume using the AP in children [16]. Another study that used the AP in children ages 8-11 years, suggested that the PMCSA was smaller in snorers, preterm children and children with sleep disorders [17].

The diagnosis of sleep disorders in children is essential, as there are many cases that are misdiagnosed by the primary care providers. Tools of diagnosis can include simple questionnaires like BEARS [18]. BEARS questionnaire is a validated sleep disturbance-screening tool for pediatric patients that fulfill the criteria for the diagnosis of sleep disorders in pediatric population[19].

Most of the SDB studies and its effects have shown the distribution in the adult population but not in children. Using the Acoustic Rhinometry to evaluate the size of the airway in children and its consequence on their sleep pattern has not been studied in the literature. Our aim in this study is to evaluate the relation of the size of the upper airway in children and their sleep pattern and circadian rhythm.

## **STUDY OBJECTIVES**

The objective of this study is to evaluate the relation between the size of the upper airway using the Acoustic Pharyngometry/Rhinometry and sleep disorders in children.

Evaluating the children's behavior in relation to the size of the upper airway and the reported disturbance in sleep is also a part of the overall study. Additionally, prevalence of mouth breathing among children and the relationship with the airway measurements using the Acoustic Pharyngometry (AP) and Acoustic Rhinometry (AR) is to be evaluated in this study. However, this paper is focusing on the first aim.

### **Study Hypotheses**

We hypothesized that children with narrower airway measured by the Acoustic Pharyngometry (AP) and Acoustic Rhinometry (AR); would show more signs of sleep disturbances.

## **METHODS**

### **Study population and inclusion criteria**

Healthy children between the ages 3-18 years; with or without sleep disturbances due to dental or skeletal disturbances and who attended the Pediatric dental clinic and Orthodontic clinic at Henry M. Goldman School of Dental Medicine were evaluated to participate in the study.

The study took place at both the Pediatric Dentistry department and the Orthodontic department of Henry M. Goldman School of Dental Medicine. The Institutional Review Board of Boston Medical Center approved this clinical study.

All included subjects completed the BEARS questionnaire (appendix 1) to evaluate sleep related difficulties and sleep disorders. The BEARS questionnaire is part of the pediatric medical history form, and this was filled for all patients at the start of the visit. The BEARS questionnaire is a tool that evaluates the major domains in the sleep and screens for sleep disorders. It was also used to determine the cases and the controls in this study. Subjects were considered cases in the study if they scored any positive response to the questions in the BEARS survey tool and controls were the ones with negative responses.

## **Exclusion Criteria**

Any subjects with medical conditions that would affect the airway size; not including the dental discrepancies. Also, young children who were uncooperative during the routine dental visits were not included in the study.

Our study aimed to evaluate the size of airway; using the Acoustic Pharyngometry and Acoustic Rhinometry; of children attended the Pediatric Dentistry and Orthodontic clinics with and without sleep disorders breathing. Subjects of the study were divided into two groups; control and case groups based on the BEARS questionnaires that determine the sleep disorders and sleep disturbance in children. The validated sleep questionnaires that were used to evaluate the sleep pattern of children showed a high sensitivity in screening for OSA[20]. Acoustic Pharyngometry/Rhinometry give mainly the volume and the CSA of the airway in a certain distance called the minimum distance[21]. To assure accuracy of Acoustic Rhinometry and Acoustic Pharyngometry measurements; a standard procedure was taken during the evaluation including the perfect seal between the mouth/nose pieces and the subjects.

Parents/ guardians of children who were eligible and agreed to participate in the study were given the patient's/parent's consent prior to participation in the study.

Following that, the study questionnaires which includes detailed questions about the subject's demographic details, medical condition, dental evaluation, behavior, sleep pattern and part of the validated Pediatric sleep questionnaire (PSQ), were given to the parents/patients. After collecting the survey, all study subjects were clinically examined to determine the profile, breathing pattern, nasal septum alignment, any nasal obstruction, skeletal evaluation, dental evaluation, transverse maxillary evaluation and vertical evaluation.

Subjects were then examined using the Eccovision Acoustic Pharyngometry (AP) and Acoustic Rhinometry (AR) (Hood Laboratories, Pembroke, MA) to obtain the airways measurements and the graphs that show the details of the dimensions of airway of included subjects. AP and AR give information about the geometry of the airway by using sound waves through the wave tubes. All tests were performed using the same technique, under similar conditions by two trained practitioners to avoid any bias during the measurements.

To record the Acoustic Pharyngometry measurements, subjects were asked to sit in a fixed position in front of the monitor. Each patient was asked to breath through the mouthpiece four times in the following pattern; inhale through mouth and exhale through mouth, inhale through nose and exhale through mouth, inhale through nose and exhale through nose and finally inhale through mouth and exhale doing Valsava maneuver. At the end of this step, the monitor demonstrated four graphs for each patient. The graphs are almost reproducible (Appendix 4-5).

The Acoustic Rhinometry measurements were recorded by asking each subject to breathe normally through the pediatric nosepiece for 3 seconds from the right nostril and another 3 seconds from the left nostril. Two graphs left and right were recorded for each patient. (Appendix 5).

The details of the recruitment and steps of the study are shown in (Figure 1).

Based on the study of Hilberg *et al*, that stated some guidelines to get accurate results of AR; the environmental conditions in which the measurements took place were standardized[14]. Therefore, in our study correct alignment of the AP and AR along with a good seal between the pieces and the mouth/ nose were considered while taking the measurements.

Acoustic Pharyngometry (AP) provided us with four pharyngographs and four major measurements were recorded in each graph. Measurements include; Pharyngometry volume (PV)

which represents the volume of the area between oropharyngeal junction to the glottis measured in cc. Pharyngometry minimum cross sectional area (PMCSA); which measures the smallest cross sectional area along the path from the oropharyngeal junction to the glottis measured in  $\text{cm}^2$  was also recorded. The last measurement seen on the graph was the Pharyngometry minimum distance (PMD); which shows the distance in centimeters in the airway from the inner incisal edges to the point in which the MCSA was measured.

Acoustic Rhinometry (AR) showed two Rhinographs (right and left). Each Rhinograph provided four basic measurements. Those measurements include; Rhinometry volume which represents the volume of the nasal airway from the nostrils to the nasopharyngeal region, measured in cc. Rhinometry minimum cross-sectional area (RMCSA); which showed the smallest cross sectional area along the path from nostrils to the nasopharynx region, measured in  $\text{cm}^2$ ; was also measured. The graph also showed Rhinometry minimum distance (RMD); which measures the distance in centimeters in the nasal airway from the nostrils to the point in which the MCSA was measured. The last measurement is the Rhinometry air resistance (RAR); which represents the pressure of the airflow during breathing in the nasal airway, measured in  $\text{cmH}_2\text{O/L/Min}$ .

Data collected in this study was recorded in a spreadsheet in a password protected drive as per HIPAA requirements. Graphs from the Eccovision Pharyngometry were transferred to the Eccovision drive and were saved in a drive that was kept in a locked cabinet throughout the duration of the study.

### **Sample size**

This is an ongoing study and the expected sample size is 300 children in both the control and case groups. However, at the time of our analysis, 123 subjects were enrolled.

### **Potential Risks and Benefits**

No known potential risks of using the Acoustic system. Beneficial information about the children's sleep pattern, behavior as well as the size of the airway by using the questionnaires, AP and AR was obtained. The parents/guardian's consent was an essential part of the study.

## STATISTICAL ANALYSIS

### Data analysis

The comparison between the case and control groups; based on the demographic information, medical conditions, behavior, sleep patterns and the Acoustic Pharyngometry/Rhinometry measurements; was completed by using STATA version 14.0 statistical software.

Since BEARS questionnaire is a tool to screen for sleep disturbance, it was used to determine cases and controls in our study. Both groups were evaluated with the measurements from the Acoustic Rhinometry and Acoustic Pharyngometry using two-sample t-test and Wilcoxon rank sum based on the normality of distribution. Evaluation of the Pharyngometry volume (PV) measurements was done using a two-sample t-test. Non-parametric Wilcoxon rank sum test was conducted for all other variables.

Linear regression was used to evaluate the relationship between the sleep disorders breathing and the Pharyngometry and Rhinometry measurements after adjusting for potential confounders (age and in some analyses; gender too). Two-sample t-test was used to compare the mean of PV among each of the following groups; snoring often, snoring always, passive smoking and overweight groups. One-way ANOVA test was used to compare the mean of PV among the three breathing pattern groups (Table 5). We set the significance level at  $\alpha= 0.05$  in all the statistical tests.

## RESULTS

To test our hypothesis, we evaluated data collected from 160 children. Thirty-seven patients did not complete the detailed study questionnaires at the time of the analysis so they were not included in the statistics described here. Therefore, the remaining participants' data analyzed in this study was for 123 children. Among them, 84 subjects completed the examination with the acoustic system (30 cases and 54 controls). The average age of the study participants in our sample was 10 years. Among those participants, there were 11% who snore always and 25% who snore sometimes. However, the case group showed increased percentage of snoring in both categories than the control group. (Table 1).

Table 1 also shows the demographic characteristics of the enrolled subjects. As overweight is a risk factor for SDB; the percentage of overweight children in both groups was evaluated (9%). The case group shows a higher percentage (64%) of overweight children than the control group (36%). The observed breathing pattern was also evaluated to see the distribution of nasal breathers, mouth breathers or through both among cases and controls. Case group (children with SDB) showed a higher percentage of mouth breathers (10%) compared to control group (4%).

Two-sample t-test was used to evaluate the relation of PV and the snoring patterns. Results showed statistically significant lower PV among those who reported snoring often (mean = 19.3) and those who did not snore ( $p < 0.05$ ). Results showed statistically significantly lower PV among those who snore always (mean = 18.7) and those who do not snore ( $p < 0.05$ ). (Table 5).

The evaluation of the relation of PV among breathing groups (mouth breathers, nose breathers or both) showed no statistical significance ( $p = 0.91$ ). The evaluation among

overweight variable and the positive passive smoking was not significant as well ( $p = 0.05$ ,  $p = 0.1$ ).

### **Acoustic Pharyngometry measurements**

The AP gave three main measurements for each subject, which includes Pharyngometry Volume (PV), Pharyngometry minimum Cross-sectional area (PMCSA), and Pharyngometry minimum distance (PMD) (Appendix 4). The mean of each of those measurements in both groups are summarized in (Table 2). The mean of the PV was lower in the case group (21.08cc) compared to the control group (22.07cc) yet, there was no statistically significant difference ( $p = 0.60$ ).

The mean of the PMCSA was slightly smaller in children with sleep disturbance ( $1.21\text{cm}^2$ ) compared to children without sleep disturbance ( $1.41\text{cm}^2$ ). However, the results were not statistically significant ( $p = 0.15$ ). The comparison of the mean of PMD in both groups was not statistically significant ( $p = 0.94$ ).

Results from the regression analysis of the PMCSA measurements of children with sleep disturbance and children without sleep disturbance after adjusting for age, gender and race; showed statistically significant results ( $p = 0.01$ ).

### **Acoustic Rhinometry measurements**

The analysis of the Acoustic Rhinometry measurements is summarized in (Table 3). Four measurements are given in each Acoustic Rhinometry graph, Rhinometry Volume (RV), Rhinometry minimum cross-sectional area (RMCSA), Rhinometry Minimum Distance (RMD) and Rhinometry Air Resistance (RAR) that represents the pressure of the airflow during breathing in the nasal airway (Appendix 5). It showed that the mean of the RV (5.92cc) and RMCSA ( $0.38\text{cm}^2$ ) in children with sleep disorders are slightly smaller than the mean in children

without sleep disturbance (6.45cc, 0.79 cm<sup>2</sup>). However, results were not statistically significant ( $p = 0.95$ ,  $p = 0.58$ ) respectively.

The results showed that the mean of RMD is lower in the case group (0.9cm) compared to the control group (1.18cm). Results of comparing the means of both groups were not statistically significant ( $p = 0.54$ ). The mean of RAR was slightly higher in the case group (5.49cmH<sub>2</sub>O/L/Min) than the control group (5.1cmH<sub>2</sub>O/L/Min). Still, the results were not statistically significant ( $p = 0.38$ ).

Regression analyses of the AR measurements while adjusting for age, gender and race are summarized in (Table 4). Results of the regression analysis of the RV showed statistically significant results between the case and control groups ( $r^2 = -0.2$ ,  $p < 0.05$ ). Thus, children with sleep disturbances had a smaller airway volume compared to the children without sleep disturbance; when controlling for age, gender and race. Results of the regression analysis of RAR showed statistically significant results ( $r^2 = 0.29$ ,  $p = 0.03$ ) when controlling for age and gender and race.

## DISCUSSION

Overall, our study results showed that there are significant differences in airway dimensions when comparing children with sleep disturbances (case group) versus children without (control group). Particularly, the PMCSA was statistically significantly lower in the case group compared to the control group ( $p = 0.01$ ). RV was statistically significantly lower in the case group compared to the control group ( $p < 0.05$ ). Rhinometry air resistance (RAR) was significantly higher in the case group than the control group ( $p = 0.03$ ).

Sleep disorders breathing can be as severe as Obstructive sleep apnea or as mild as snoring [22]. Previous studies reported the prevalence of OSAS and sleep disorders breathing in children to range between 2-3% [23]. In our study we intended to get detailed information through the validated PSQ about the subjects' sleep pattern and circadian rhythm, including signs of OSA, primary snoring and episodes of cessation of breathing during sleep. All those findings given in the survey were then evaluated for association with the Acoustic Rhinometry and Acoustic Pharyngometry measurements.

The upright airway measurements given by the Acoustic Pharyngometry and Acoustic Rhinometry of pediatric population were significantly smaller in subjects with snoring only than subjects with OSA [22]. A study that evaluated the nasal volume using Acoustic Rhinometry in healthy children reported a lower nasal volume (2.03-2.05cc) among the study group than the measurements we found in our study [13]. In our analysis, the mean of RV was 5.92cc (in case group) and 6.45cc (in the control group). The same study reported that gender and age had no significant differences on the measurement values [13]. Our study reported a significantly lower Rhinometry volume in the case group (mean: 5.92cc) compared to the control group ( $r^2 = -0.92$ ,  $p$

<0.05). Our study showed statistically significant results of age with the AR measurements. However, there was no statistical results of gender with either AR or AP measurements.

Other studies that used the Acoustic Rhinometry measurements in children reported lower values for the volume but similar values as we got for the mean of RMCSA (0.38 for case group, 0.79 for control group)[24]. A study for Riechelmann *et al.*, reported the mean of RMCSA in children to be 0.29 +/- 0.06 cm<sup>2</sup> [10]. Our study reported a bigger RMCSA in both groups. However, the difference between the case and control group in RMCSA was not statistically significant ( $p = 0.07$ ).

The smaller size of the epi-pharyngeal space does not necessarily causes OSA in children [25]. However, other studies showed that the decrease in the pharyngeal space caused by enlarged tonsils and adenoids are possible risk factors of OSA and SDB[25, 26]. Our study showed that the group that had sleep disturbance had a significantly smaller CSA of the pharynx using the Acoustic Pharyngometry than the group without sleep disturbance ( $r^2=-.21$ ,  $p=0.02$ ). (Table 1, Table3).

As our sample was selected from patients who attended BU dental school; a selection bias is possible. The polysomnography stays as the gold standard for the diagnosis of OSA. The fact that the Acoustic Rhinometry/Pharyngometry give measurements of the nasopharynx /oropharynx only, and that the narrowing could be in deeper parts of the airway gives our study a limitation. Other limitations in our study are the subjective nature of the questions in the PSQ and BEARS questionnaires. Other risk factors of SDB like obesity, skeletal and dental classification, and other medical conditions were evaluated in the overall questionnaires of our study but not in this analysis. Further analysis is needed to evaluate those risk factors.

Sleep disturbance and obstructive sleep apnea can cause episodes of the partial or complete stopping of the airflow and gasping for air during sleep, apnea and reduction of the levels of blood Oxygen [23]. Thus, it is very important to be able to diagnose those disorders early in children. Using the Acoustic Pharyngometry/ Rhinometry along with PSQ is a non-invasive way to evaluate the possibility of having SDB.

Further and broader evaluation of the association between the size of the airway using the Acoustic Pharyngometry/Rhinometry and the sleep disorders breathing in children should be done to confirm our findings.

## **CONCLUSION**

Acoustic Pharyngometry/ Rhinometry is a manageable non-invasive way to measure the airway in children. Although we were not able to achieve a definite diagnosis of SDB using part of the PSQ, it still gives valuable information about the children's sleep pattern. The Rhinometry volume was significantly lower in children with SDB compared to children without SDB. The Pharyngometry MCSA was significantly lower in children with SDB compared to children without SDB. Our findings of the correlation between the narrow size of the airway and the sleep disorders suggest that providers should focus on the airway of children as well as their sleep pattern as a part of their routine. Using BEARS questionnaires as a part of the medical history by the Pediatric dentistry providers may give a better chance for the early diagnosis of sleep disturbance breathing in children.

## APPENDIX

### Appendix 1: Tables

	<b>Controls n=54</b>	<b>Cases n=30</b>	<b>All subjects n=84</b>
Age, years Mean $\pm$ SD	11 $\pm$ 3.38	10 $\pm$ 4.15	10 $\pm$ 4
Male (%)	67	33	51
Female (%)	60	40	49
Race (%)			
White	71	29	33
African American	58	42	48
Asian	86	14	6
American Indian	0	0	0
Native Hawaiian/Other	56	44	13
Snoring pattern (%)			
Snore often	19	81	25
Snore always	8	85	11
Never snores	79	38	74
Overweight (%)	36	64	9
Smoking parents (%)	9	23	10

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Breathing pattern (%)			
Mouth only	4	10	4
Nose only	54	27	38
Both	42	63	54

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**Table 1: Mean of Demographic characteristics of case and control groups**

	Controls n=54 Mean	Cases n=30 Mean	<i>p</i> -value
Pharyngometer Volume (cc)	22.07	21.08	0.6
Pharyngometer MCSA (cm <sup>2</sup> )	1.41	1.21	0.15
Pharyngometer Minimum Distance (cm)	11.9	11.2	0.94

**Table 2: Univariate analysis describing differences in various Acoustic Pharyngometry measurements between cases and controls.**

	Controls n=54 Mean	Cases n=30 Mean	<i>p</i> -value
Rhinometry Volume (cc)	6.45	5.92	0.95
Rhinometry MCSA (cm <sup>2</sup> )	0.79	0.38	0.58
Rhinometry Minimum Distance (cm)	1.18	0.9	0.54
Rhinometry air resistance (CmH <sub>2</sub> O/L/Min)	5.1	5.49	0.38

**Table 3: Univariate analysis describing differences in various Acoustic Rhinometry measurements between cases and controls.**

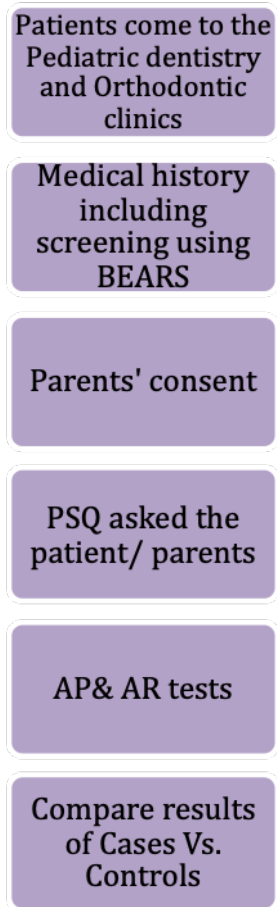
	$r^2$	$p$ -value
Rhinometry volume	-0.2	<0.05
Rhinometry MCSA	-0.22	0.07
Rhinometry Air resistance	0.29	0.03
Pharyngometry volume	-0.79	0.88
Pharyngometry MCSA	-0.17	0.01

**Table 4: Regression analyses models for the evaluation AP/AR measurements among cases and controls adjusting for age, gender and race.**

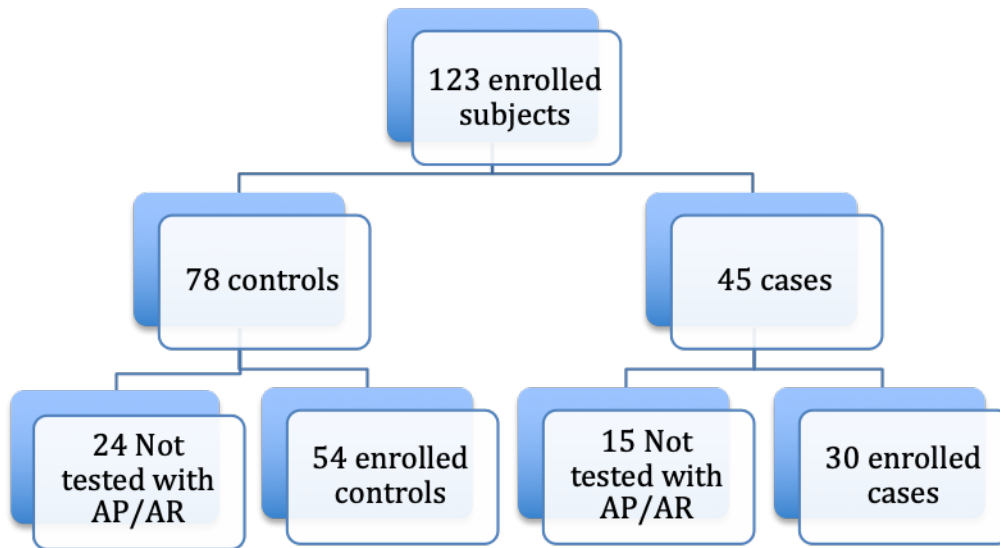
	<i>Mean of PV</i>	<i>p-value</i>
Snoring pattern:		
Snore often (yes versus no)	19.3	<0.05
Snore always (yes versus no)	18.7	<0.05
Breathing pattern:		
		0.91
Mouth only	22.3	
Nose only	21.8	
Both	22.6	
Overweight	24.65	0.05
Passive Smoking	26.3	0.10

**Table 5: *p*-values of Univariate analyses that evaluated the mean of PV among snoring, breathing patterns groups, overweight and passive smoking.**

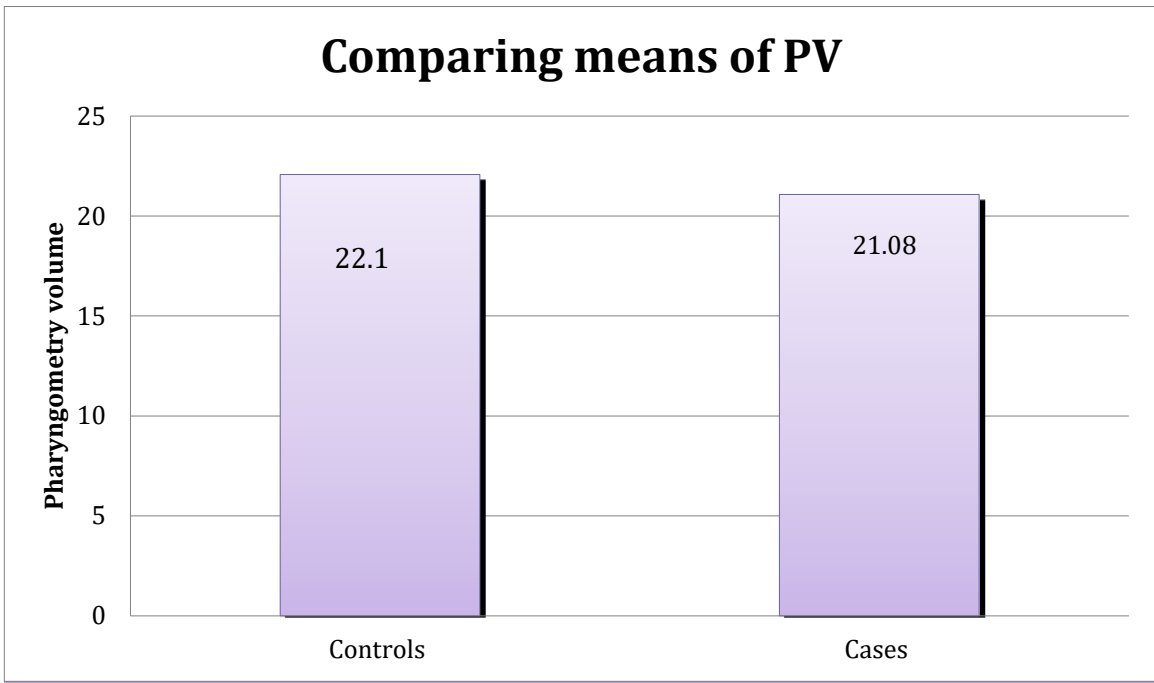
## Appendix 2: Figures



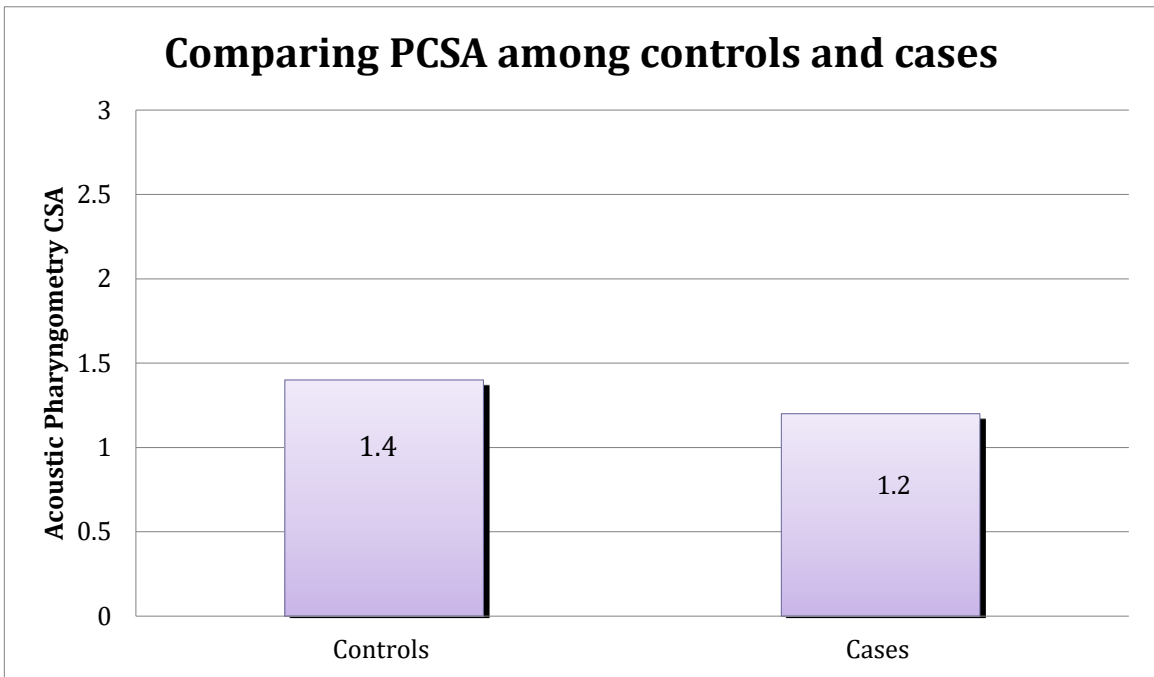
**Figure 1: Steps taken for the enrollment and measurements.**



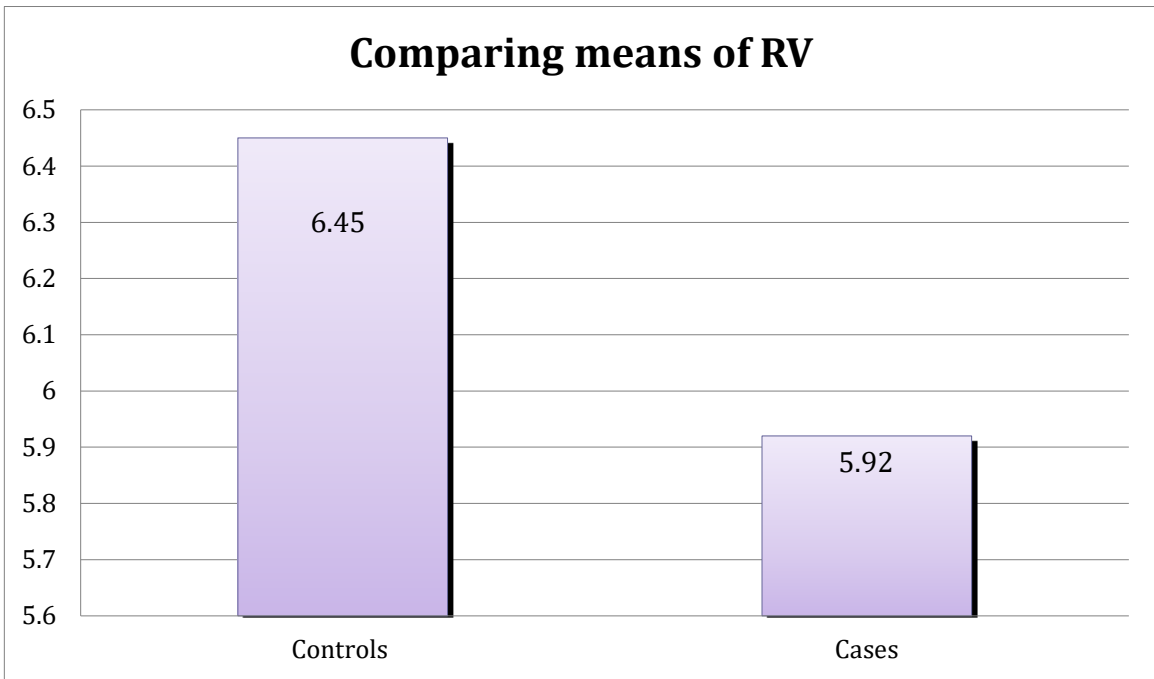
**Figure 2: Number of subjects enrolled in the study.**



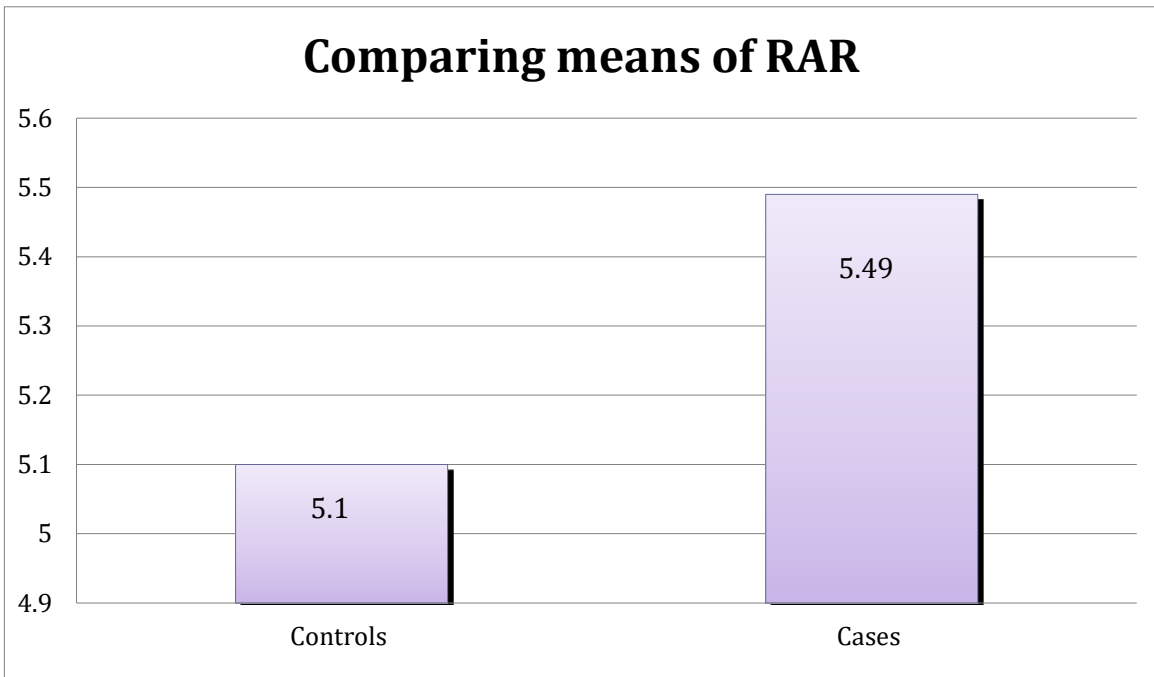
**Figure 3: Means of Acoustic Pharyngometer volume among controls and cases.**



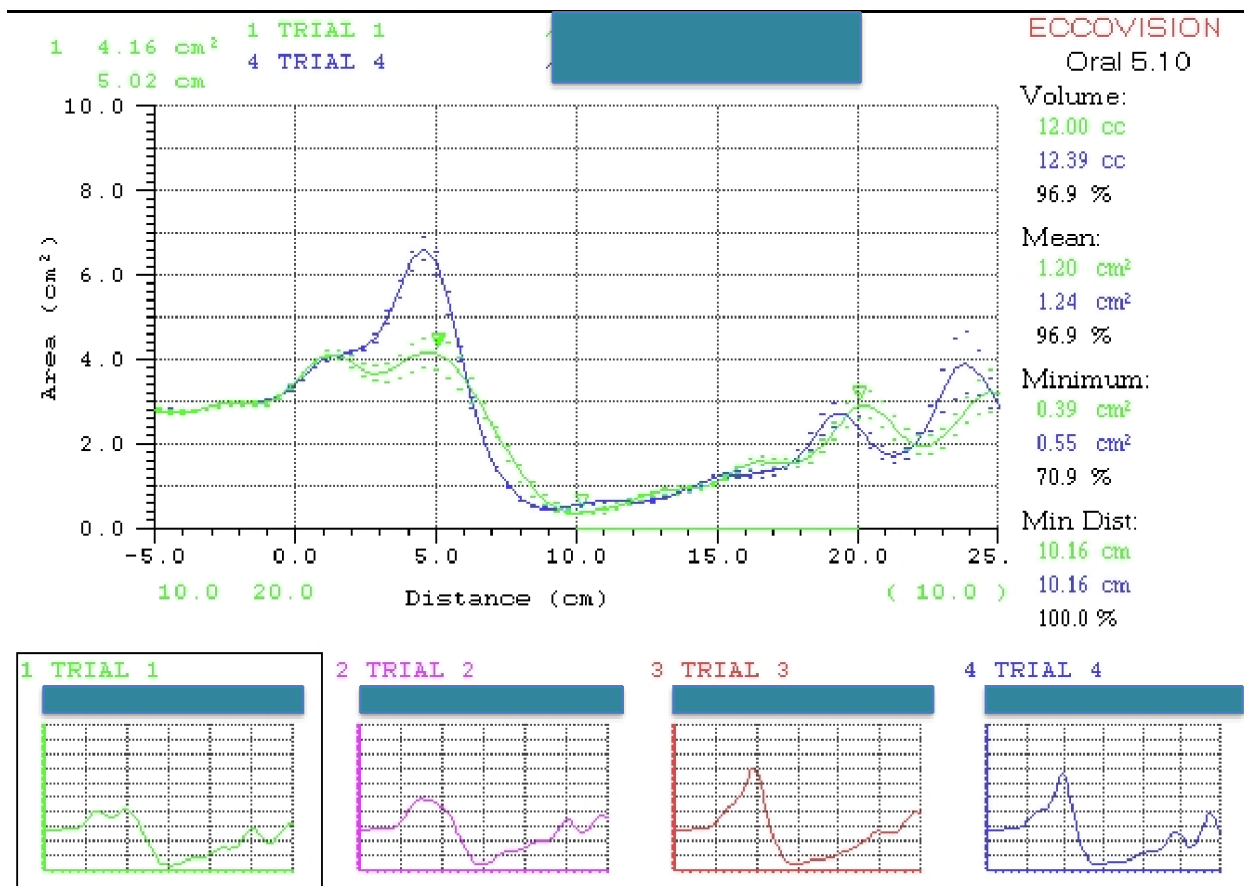
**Figure 4: Means of Acoustic Pharyngometer CSA among controls and cases.**



**Figure 5: Comparing means of Rhinometry volume among controls and cases.**



**Figure 6: Means of Rhinometry air resistance among controls and cases.**



**Figure 7: An example of Acoustic Pharyngograph of a case with sleep disturbance.**

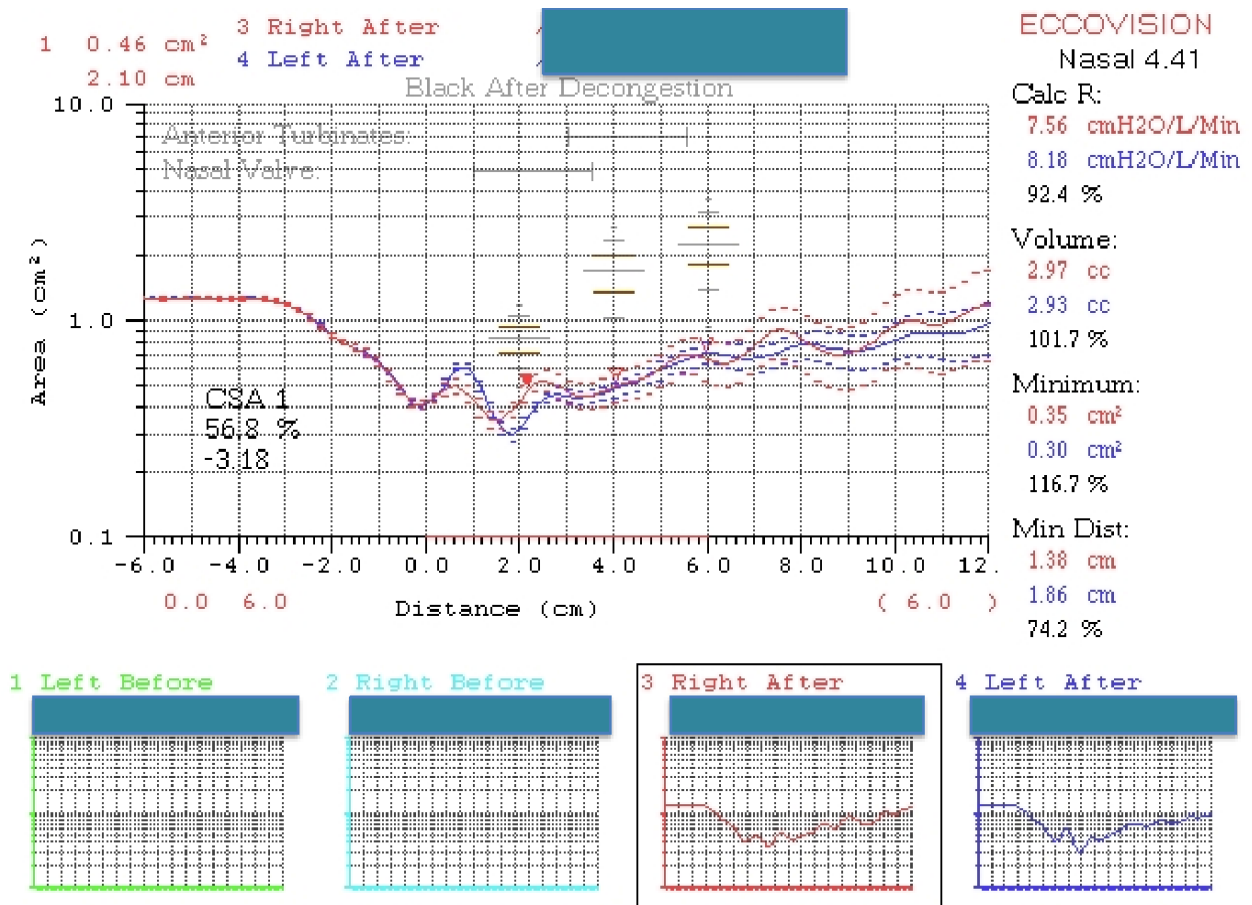
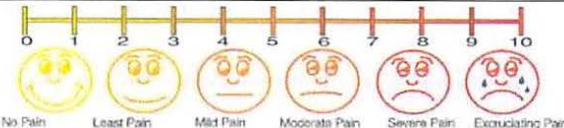


Figure 8: An example of Acoustic Rhinograph of a control without sleep disturbance.

### Appendix 3: Medical history form includes BEARS questionnaires

 Henry M. Goldman School of Dental Medicine  
**PEDIATRIC MEDICAL & DENTAL QUESTIONNAIRE**

TODAY'S DATE:		RECORD No:	
Patient Name:		Age:	Birthdate (MM/DD/YYYY):
Home Address:		Phone number Home: Cell:	
Height (ft./in.):	Weight(lbs):	Gender: <input type="checkbox"/> Male <input type="checkbox"/> Female	Ethnicity: <input type="checkbox"/> Hispanic <input type="checkbox"/> Non-Hispanic <input type="checkbox"/> Prefer not to answer
Race: <input type="checkbox"/> White <input type="checkbox"/> Asian <input type="checkbox"/> Native Hawaiian or other <input type="checkbox"/> African-American <input type="checkbox"/> American Indian <input type="checkbox"/> Prefer not to answer			
Parent/Guardian Name:		Relationship to Patient:	
Preferred language of communication:		Would you like to have an interpreter when you speak with the health care provider or team? <input type="checkbox"/> YES <input type="checkbox"/> NO	
Highest level of education completed by parent/legal guardian: <input type="checkbox"/> No formal schooling <input type="checkbox"/> Primary school completed <input type="checkbox"/> High school completed <input type="checkbox"/> Prefer not to answer <input type="checkbox"/> Less than primary school <input type="checkbox"/> Secondary school completed <input type="checkbox"/> College or University completed			
<b>MEDICAL HISTORY</b>			
1. Does your child have any <b>allergies</b> (medications, food)? If YES please explain:			<input type="checkbox"/> YES <input type="checkbox"/> NO
2. Has your child been diagnosed with bleeding disorders, heart conditions, seizures, or cancer? If YES please explain:			<input type="checkbox"/> YES <input type="checkbox"/> NO
3. Has your child's physician told you that your child needs antibiotic treatment prior to any dental procedure?			<input type="checkbox"/> YES <input type="checkbox"/> NO
4. Has your child been diagnosed with any other medical condition? If YES, what is the diagnosed condition? If YES, has the above condition lasted more than 12 months?			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> YES <input type="checkbox"/> NO
5. Does your child <u>currently</u> use medication(s) prescribed by a doctor, other than vitamins? If YES please specify:			<input type="checkbox"/> YES <input type="checkbox"/> NO
6. Does your child need <b>more</b> medical care, mental health or educational services than is <b>usual</b> for most children of the same age?			<input type="checkbox"/> YES <input type="checkbox"/> NO
7. Is your child limited or prevented in any way in his/her ability to do the things that most children of the same age do?			<input type="checkbox"/> YES <input type="checkbox"/> NO
8. Does your child need or get special therapy such as physical, occupational or speech therapy?			<input type="checkbox"/> YES <input type="checkbox"/> NO
9. Does your child have any kind of emotional, developmental or behavioral problems for which he/she needs treatment or counseling?			<input type="checkbox"/> YES <input type="checkbox"/> NO
10. During the past 12 months how often has the child's condition (medical, behavioral, emotional or developmental) affected his/her ability to perform daily activities in school or at home? <input type="checkbox"/> Never <input type="checkbox"/> Rarely <input type="checkbox"/> Usually <input type="checkbox"/> Always <input type="checkbox"/> Don't know			
11. Does your child experience difficulty with any of the following: <input type="checkbox"/> Breathing (Respiratory problems) <input type="checkbox"/> Hearing <input type="checkbox"/> Eyesight <input type="checkbox"/> Sleeping <input type="checkbox"/> Self care (eating/dressing/bathing) <input type="checkbox"/> Paying attention/listening <input type="checkbox"/> Speaking/communicating verbally <input type="checkbox"/> Anxiety/depression			

12. Does your child see a specialist(s) to receive treatment for any condition listed above? If YES, please complete the following: Doctor's name: Specialty field: Doctor's Phone number:	<input type="checkbox"/> YES <input type="checkbox"/> NO
13. Does your child have any of the listed habits? (currently or had in the past) <input type="checkbox"/> Thumbsucking <input type="checkbox"/> Mouthbreathing <input type="checkbox"/> Tongue thrusting <input type="checkbox"/> Nailbiting <input type="checkbox"/> Teeth grinding	
14. Does the child have trouble sleeping or has the child been diagnosed with a sleeping disorder by a health professional?	<input type="checkbox"/> YES <input type="checkbox"/> NO
15. Is the child on a special diet?	<input type="checkbox"/> YES <input type="checkbox"/> NO
16. Does the child currently use a baby bottle to drink milk? If YES, does the child sleep with the bottle?	<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> YES <input type="checkbox"/> NO
17. How often does the child drink apple juice, carbonated drinks (sodas), lemonade or other soft drinks? <input type="checkbox"/> $\geq 2$ /day <input type="checkbox"/> 1 /day <input type="checkbox"/> $\geq 2$ /week <input type="checkbox"/> 1 /week <input type="checkbox"/> $\geq 2$ /month <input type="checkbox"/> 1/month <input type="checkbox"/> Never	
18. How often does the child eat snacks between meals? <input type="checkbox"/> $\geq 2$ /day <input type="checkbox"/> 1 /day <input type="checkbox"/> $\geq 2$ /week <input type="checkbox"/> 1 /week <input type="checkbox"/> $\geq 2$ /month <input type="checkbox"/> 1/month <input type="checkbox"/> Never	
<b>DENTAL HISTORY &amp; ORAL HEALTH</b>	
19. Is this the child's first visit to a dentist? If NO, what is the date of last dental exam (mm/dd/yyyy):	<input type="checkbox"/> YES <input type="checkbox"/> NO
20. Does the child have a dental problem today?	<input type="checkbox"/> YES <input type="checkbox"/> NO
21. Has the child ever received local anesthetic (Novocaine) previously?	<input type="checkbox"/> YES <input type="checkbox"/> NO
22. Is the child experiencing pain today? If YES, please ask child to select the level of pain	<input type="checkbox"/> YES <input type="checkbox"/> NO
	
23. During the past 3 months how much pain or distress have your teeth or gums caused you? <input type="checkbox"/> A great deal <input type="checkbox"/> Quite a bit <input type="checkbox"/> Some <input type="checkbox"/> A little bit <input type="checkbox"/> Not at all	
24. In the past 3 months, has the child had difficulty eating normally because of dental pain/problems?	<input type="checkbox"/> YES <input type="checkbox"/> NO
25. In the past 3 months, how often did the child feel self-conscious, nervous or unhappy because of problems in the mouth, teeth or gums?	<input type="checkbox"/> Never <input type="checkbox"/> Sometimes <input type="checkbox"/> Always
26. In the past 3 months, has the child missed school because of pain or discomfort in the teeth or mouth? If YES how often: <input type="checkbox"/> Once/month <input type="checkbox"/> 2 times/month <input type="checkbox"/> 3 times/month <input type="checkbox"/> >3 times/month	<input type="checkbox"/> YES <input type="checkbox"/> NO
27. Who brushes the child's teeth?	<input type="checkbox"/> CHILD <input type="checkbox"/> PARENT <input type="checkbox"/> OTHER
28. How many times per day does the child brush his/her teeth?	<input type="checkbox"/> 0 <input type="checkbox"/> 1 <input type="checkbox"/> $\geq 2$
29. Does the child use fluoride based toothpaste?	<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> DO NOT KNOW
30. How many times per day does the child floss his/her teeth per day?	<input type="checkbox"/> 0 <input type="checkbox"/> 1 <input type="checkbox"/> $\geq 2$
31. Does the child drink tap water?	<input type="checkbox"/> YES <input type="checkbox"/> NO
32. Is the tap water at home fluoridated?	<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> DO NOT KNOW

May 2011

**COMPLETE ONLY ONE TABLE BELOW BASED ON CHILD'S AGE**  
**P – Questions to be directed to parent; C – Questions directed to the child**

<b>TABLE A</b>		<b>Preschool (2 – 5 YEARS)</b>	
Bedtime problems	Does your child have any problems going to bed?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Falling asleep?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Excessive day-time sleepiness	Does your child seem over tired or sleepy a lot during the day?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Does your child still take naps?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Awakenings during night	Does your child wake up a lot at night?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Regularity and duration of sleep	Does your child have a regular bedtime and wake time?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	What are they?	Bedtime	am/pm
		Waketime	am/pm
Sleep-disordered breathing	Does your child snore a lot or have difficulty breathing at night?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Does your child breathe mainly through the nose or mouth?	<input type="checkbox"/> Nose	<input type="checkbox"/> Mouth <input type="checkbox"/> Don't know
<b>TABLE B</b>		<b>School-aged (6 – 12 YEARS)</b>	
Bedtime problems	Does your child have any problems at bedtime? (P)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Do you have any problems going to bed? (C)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Excessive day-time sleepiness	Does your child have difficulty waking in the morning, seem sleepy during the day or take naps? (P)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Do you feel tired a lot? (C)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Awakenings during night	Does your child seem to wake up a lot at night?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Any sleep walking or nightmares? (P)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Do you wake up a lot at night? Have trouble getting back to sleep? (C)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Regularity and duration of sleep	How many hours of sleep does the child get?	School day	hours
		Weekend	hours
	Do you think he/she is getting enough sleep? (P)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Sleep-disordered breathing	Does your child have loud or nightly snoring or any breathing difficulties at night? (P)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Do you breathe mainly through the nose or mouth (C)?	<input type="checkbox"/> Nose	<input type="checkbox"/> Mouth <input type="checkbox"/> Don't know
<b>TABLE C</b>		<b>Adolescent (13 – 18 YEARS)</b>	
Bedtime problems	Do you have any problems falling asleep at bedtime? (C)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Excessive day-time sleepiness	Do you feel sleepy a lot during the day? In school? While driving (if applicable)? (C)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Awakenings during night	Do you wake up a lot at night?	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Have trouble getting back to sleep? (C)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
Regularity and duration of sleep	What time do you usually go to bed on school nights? Weekends?	School night	am/pm
		Weekend	am/pm
	How much sleep do you usually get? (C)	hours	
Sleep-disordered breathing	Does your teenager snore loudly or nightly? (P)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
	Do you breathe mainly through the nose or mouth (C)?	<input type="checkbox"/> Nose	<input type="checkbox"/> Mouth <input type="checkbox"/> Don't know

## Appendix 4: Study Questionnaire

### Sleep and breathing patterns in childhood Study Questionnaire

#### Background Information:

1. Today's date (mm/dd/yy):
2. Name:
3. Date of birth (mm/dd/yy):
4. Age (years):
5. Gender:
6. Height (cms):
7. Weight (kgs):
8. Race/ethnicity:  
 White  African-American  Asian  American Indian  Native Hawaiian/ other
9. Ethnicity:  
 Hispanic  Non-Hispanic
10. Living with parents?  Yes  No
11. Schooling:  Home-schooling  Schooling outside
12. Smoking at home/Parental smoking  Yes  No
13. If yes to 12 then please answer the following:  
 One parent smokes  
 Both parents smoke
14. Has your child been diagnosed with ADD/ADHD (Attention deficit disorders)?  
 Yes  No
15. Has your child been diagnosed with any medical condition?  Yes  No
16. If YES to 13 is your child taking medications for this condition?  Yes  No
17. Does your child have a history of allergies?  Yes  No
18. Does your child currently have seasonal allergies?  Yes  No

19. Does your child use any medications currently to control allergies?  Yes  No
20. Does your child currently have a nasal congestion (common cold)?  Yes  No
21. Does your child have breathing difficulties?  Yes  No

**Pediatric Sleep Questionnaire (PSQ):**

22. While sleeping, does your child....
- a. Snore more than half the time?  YES  NO
  - b. Always snore?  YES  NO
  - c. Snore loudly?  YES  NO
  - d. Have ``heavy" or loud breathing?  YES  NO
  - e. Have trouble breathing, or struggle to breathe?  YES  NO
  - f. Have you ever seen your child stop breathing during the night?  YES  NO
23. Does your child ....
- a. Tend to breathe through the mouth during the day?  YES  NO
  - b. Have a dry mouth on waking up in the morning?  YES  NO
  - c. Occasionally wet the bed?  YES  NO
  - d. Wake Up feeling unrefreshed in the morning?  YES  NO
  - e. Have a problem with sleepiness during the day?  YES  NO
  - f. Have a teacher or other supervisor who commented that your child appears sleepy during the day?  YES  NO
  - g. Find it hard to wake your child up in the morning?  YES  NO
  - h. Wake up with headaches in the morning?  YES  NO
24. Did your child stop growing at a normal rate at any time since birth?  YES  NO
25. Is your child overweight?  YES  NO

26. This child often.....
- |  |                              |                             |
|--|------------------------------|-----------------------------|
| a. Does not seem to listen when spoken to directly.                              | <input type="checkbox"/> YES | <input type="checkbox"/> NO |
| b. Has difficulty organizing task and activities.                                | <input type="checkbox"/> YES | <input type="checkbox"/> NO |
| c. Is easily distracted by extraneous stimuli.                                   | <input type="checkbox"/> YES | <input type="checkbox"/> NO |
| d. Fidgets with hands or feet or squirms in seat.                                | <input type="checkbox"/> YES | <input type="checkbox"/> NO |
| e. Is 'on the go' or often acts as if 'driven by a motor'.                       | <input type="checkbox"/> YES | <input type="checkbox"/> NO |
| f. Interrupts or intrudes on others<br>(e.g. butts into conversations or games). | <input type="checkbox"/> YES | <input type="checkbox"/> NO |

**Clinical Examination:**

27. Patient profile:

28. Observed breathing pattern:

- Mouth only
- Nose only
- Both

29. Nasal septum deviation:

- Yes
- No

30. Any nasal obstruction (due to trauma or other medical reasons)?

- Yes
- No

31. Skeletal classification:

- Class 1 (Maxillary mandibular dental protrusion or retrusion)
- Class 2 (Maxillary protrusion and/or mandibular retrognathism)
- Class 3 (Maxillary retrognathism and/or mandibular protrusion/prognathism)

32. Dental classification:

- Class I (normal alignment of upper and lower teeth)
- Class II (Maxillary protrusion present/Upper teeth are more forward/Convex appearance)
- Class III (Mandibular protrusion present/Lower teeth are more forward/Concave appearance)

33. Transverse maxillary evaluation:

- Maxillary constriction with unilateral posterior cross-bite
- Maxillary constriction with bilateral posterior cross-bite
- Maxillary constriction without posterior cross-bite

34. Vertical evaluation of patient (for orthodontic patients with cephalograms)

- Hypo-divergent vertical pattern
- Normo-divergent vertical pattern
- Hyper-divergent vertical pattern

35. Nasal airway measurement:

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36. Pharyngeal measurement:

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Thank you for your participation!

## Appendix 5: Pediatric Sleep Questionnaires

### While sleeping, does your child...

- A1 ... ever snore?
- A2 ... snore more than half the time?**
- A3 ... always snore?**
- A4 ... snore loudly?**
- A5 ... have “heavy” or loud breathing?**
- A6 ... have trouble breathing, or struggle to breathe?**

### Have you ever ...

- A7 ... seen your child stop breathing during the night?**
- A8 ... been concerned about your child's breathing during sleep?
- A9 ... had to shake your sleeping child to get him or her to breathe, or wake up and breathe?
- A11 ... seen your child wake up with a snorting sound?
- A12 Does your child have restless sleep?
- A15 At night, does your child usually become sweaty, or do the pajamas usually become wet with perspiration?
- A17 At night, does your child usually get out of bed to urinate?
- A21 Does your child usually sleep with the mouth open?
- A22 Is your child's nose usually congested or “stuffed” at night?
- A23 Do any allergies affect your child's ability to breathe through the nose?

### Does your child ...

- A24 ... tend to breathe through the mouth during the day?**
- A25 ... have a dry mouth on waking up in the morning?**
- A27 ... complain of an upset stomach at night?
- A29 ... get a burning feeling in the throat at night?
- A30 ... grind his or her teeth at night?
- A32 ... occasionally wet the bed?**

**Does your child ...**

- B1** ... wake up feeling *unrefreshed* in the morning?
- B2** ... have a problem with sleepiness during the day?
- B3** ... complain that he or she feels sleepy during the day?
- B4** **Has a teacher or other supervisor commented that your child appears sleepy during the day?**
- B5** Does your child usually take a nap during the day?
- B6** **Is it hard to wake your child up in the morning?**
- B7** **Does your child wake up with headaches in the morning?**
- B9** **Did your child stop growing at a normal rate at any time since birth?**
- B22** **Is your child overweight?**

**This child often ...**

- C1** ... fails to give close attention to details or makes careless mistakes in schoolwork, work or other activities
- C2** ... often has difficulty sustaining attention in tasks or play activities
- C3** ... **does not seem to listen when spoken to directly**
- C4** ... does not follow through on instructions and fails to finish schoolwork, chores or duties
- C5** ... **has difficulty organizing task and activities**
- C6** ... avoids, dislikes, or is reluctant to engage in tasks or activities that require sustained mental effort (such as homework or schoolwork)
- C7** ... loses things necessary for tasks or activities (e.g. toys, school assignments, pencils, books or tools)
- C8** ... **is easily distracted by extraneous stimuli**
- C9** ... is forgetful in daily activities
- C10** ... **fidgits with hands or feet or squirms in seat**
- C11** ... leaves seat in classroom or in other situations in which remaining seated is expected

- C12 ... runs about or climbs excessively in situations in which it is inappropriate
- C13 ... has difficulty playing or engaging in leisure activities quietly
- C14 ... is 'on the go' or often acts as if 'driven by a motor'**
- C15 ... talks excessively
- C16 ... blurts out answers before questions have been completed
- C17 ... has difficulty awaiting his/her turn
- C18 ... interrupts or intrudes on others (e.g. butts into conversations or games)**

## BIBLIOGRAPHY

1. Baris, H.E., et al., *Clinical and polysomnographic features of children evaluated with polysomnography in pediatric sleep laboratory*. Turk Pediatri Ars, 2017. **52**(1): p. 23-29.
2. Redline, S., et al., *Risk factors for sleep-disordered breathing in children. Associations with obesity, race, and respiratory problems*. Am J Respir Crit Care Med, 1999. **159**(5 Pt 1): p. 1527-32.
3. Beydon, N. and G. Aubertin, [*Diagnostic criteria for obstructive sleep apnea syndrome*]. Arch Pediatr, 2016.
4. Kaditis, A.G., et al., *Obstructive sleep disordered breathing in 2- to 18-year-old children: diagnosis and management*. Eur Respir J, 2016. **47**(1): p. 69-94.
5. Young, T., et al., *The Occurrence of Sleep-Disordered Breathing among Middle-Aged Adults*. New England Journal of Medicine, 1993. **328**(17): p. 1230-1235.
6. Marcus, C.L., et al., *Diagnosis and management of childhood obstructive sleep apnea syndrome*. Pediatrics, 2012. **130**(3): p. e714-55.
7. Crabtree, V.M., J.W. Varni, and D. Gozal, *Health-related quality of life and depressive symptoms in children with suspected sleep-disordered breathing*. Sleep, 2004. **27**(6): p. 1131-8.
8. Com, G., et al., *Characteristics and surgical and clinical outcomes of severely obese children with obstructive sleep apnea*. J Clin Sleep Med, 2015. **11**(4): p. 467-74.
9. Guilleminault, C., et al., *Missing teeth and pediatric obstructive sleep apnea*. Sleep Breath, 2015.
10. Riechelmann, H., M.C. Rheinheimer, and M. Wolfensberger, *Acoustic rhinometry in pre-school children*. Clin Otolaryngol Allied Sci, 1993. **18**(4): p. 272-7.
11. Straszek, S.P., et al., *Reference values for acoustic rhinometry in children from 4 to 13 years old*. Am J Rhinol, 2008. **22**(3): p. 285-91.
12. Straszek, S.P., et al., *Reference values for acoustic rhinometry in decongested school children and adults: the most sensitive measurement for change in nasal patency*. Rhinology, 2007. **45**(1): p. 36-9.
13. Qian, W., et al., *Acoustic rhinometry in preschool children*. Otolaryngol Head Neck Surg, 2007. **137**(1): p. 39-42.
14. Hilberg, O. and O.F. Pedersen, *Acoustic rhinometry: recommendations for technical specifications and standard operating procedures*. Rhinol Suppl, 2000. **16**: p. 3-17.

15. Grymer, L.F., *Clinical applications of acoustic rhinometry*. Rhinol Suppl, 2000. **16**: p. 35-43.
16. Hatzakis, G.E., et al., *Acoustic reflectance of pharyngeal structures in children*. Int J Pediatr Otorhinolaryngol, 2003. **67**(4): p. 373-81.
17. Monahan, K.J., et al., *Utility of noninvasive pharyngometry in epidemiologic studies of childhood sleep-disordered breathing*. Am J Respir Crit Care Med, 2002. **165**(11): p. 1499-503.
18. Owens, J.A. and V. Dalzell, *Use of the 'BEARS' sleep screening tool in a pediatric residents' continuity clinic: a pilot study*. Sleep Med, 2005. **6**(1): p. 63-9.
19. Spruyt, K. and D. Gozal, *Pediatric sleep questionnaires as diagnostic or epidemiological tools: a review of currently available instruments*. Sleep Med Rev, 2011. **15**(1): p. 19-32.
20. Ehsan, Z., et al., *Validation of the pediatric sleep questionnaire in children with asthma*. Pediatr Pulmonol, 2017. **52**(3): p. 382-389.
21. Corey, J.P., et al., *Normative standards for nasal cross-sectional areas by race as measured by acoustic rhinometry*. Otolaryngol Head Neck Surg, 1998. **119**(4): p. 389-93.
22. Okun, M.N., et al., *Acoustic rhinometry in pediatric sleep apnea*. Sleep Breath, 2010. **14**(1): p. 43-9.
23. Ali, N.J., D.J. Pitson, and J.R. Stradling, *Snoring, sleep disturbance, and behaviour in 4-5 year olds*. Arch Dis Child, 1993. **68**(3): p. 360-6.
24. Miyamoto, Y., K. Takeuchi, and Y. Majima, *Measurement of nasal patency by acoustic rhinometry in Japanese school children*. Auris Nasus Larynx, 2009. **36**(4): p. 406-10.
25. Nieminen, P., et al., *Snoring children: factors predicting sleep apnea*. Acta Otolaryngol Suppl, 1997. **529**: p. 190-4.
26. Brietzke, S.E., E.S. Katz, and D.W. Roberson, *Can history and physical examination reliably diagnose pediatric obstructive sleep apnea/hypopnea syndrome? A systematic review of the literature*. Otolaryngol Head Neck Surg, 2004. **131**(6): p. 827-32.

## CURRICULUM VITAE

