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Cephalometric Assessment of Snoring and Nonsnoring Children*

Randall Kulnis, DMD, MSD†; Suchitra Nelson, PhD; Kingman Strohl, MD, FCCP; and Mark Hans, DDS, MSD

Study objective: **To determine the differences in craniofacial cephalometric variables between snoring and nonsnoring children.**
Design: **Cross-sectional.**
Setting: **Case Western Reserve University Dental School, Department of Orthodontics, and local Cleveland orthodontic private practices.**
Patients: **Twenty-eight snoring and 28 nonsnoring children between the ages of 7 years and 14 years. Nonsnoring subjects were matched to snoring subjects by age, sex, and ethnicity (mean [± SD] age, 10 ± 2 years; 82% white, 64% female).**
Interventions: **None.**
Measurements: **Snoring was assessed using a sleep behavior questionnaire administered to parents or guardians. The cephalometric radiographs of the study subjects were traced by a single investigator, and 1 angular measurement and 11 linear measurements of hard and soft tissues were recorded. The paired Student's *t* test was used to analyze the cephalometric data.**
Results: **Snoring children manifest a significantly narrower anterior-posterior dimension of the pharynx at the superior and most narrow widths. Snoring children also had a greater length from the hyoid to the mandibular plane.**
Conclusions: **Snoring children appear to present craniofacial factors that differ from those of nonsnoring children.** ***(CHEST 2000; 118:596–603)***

Key words: cephalometry; children; snoring

Abbreviations: A–PNS = anterior-posterior length of the maxilla measured from A-point to the posterior nasal spine; BMI = body mass index; Go–Gn = effective length of the body of the mandible measured from gonion to gnathion; H–MP = hyoid to mandibular plane; MCF = middle cranial fossa; N–PAS = width of the pharyngeal airway at its most narrow point inferior to the PNS and superior to gonion; OPA = oropharyngeal airway; OSAHS = obstructive sleep apnea-hypopnea syndrome; PM = boundary that separates the anterior cranial fossa and nasomaxillary complex from the middle cranial fossa and pharynx; PNS = posterior nasal spine; S–N = linear measurement from sella turcica to nasion; S–PAS = width of the pharyngeal airway at the most posterior-superior point on the soft palate; TL = tongue length; VAL = vertical airway length measured from the PNS to the base of the epiglottis

Snoring was once considered to be harmless,[1] but now is suggested to be indicative of a significant clinical problem such as obstructive sleep apnea-hypopnea syndrome (OSAHS), whose medical consequences range from no physical debilitation to failure to thrive.[2,3] It is estimated that as many as 70% of adults with OSAHS snored during childhood.[4] Those with OSAHS are at increased risk for hypertension, cardiovascular disease, cerebrovascular disease, and impaired function caused by sleepiness.[4–8]

Epidemiologic studies of habitual snoring in children suggests a prevalence of between 7% and 12%.[9–12] Snoring children are reportedly mouth breathers[11,13] or restless sleepers,[9–11] have excessive daytime sleepiness,[9,10] are hyperactive,[9,10] have poorer hearing,[11] and present with previous adenoidectomy and enlarged tonsils.[14] Although snoring has been reported to be a common finding in children with symptomatic OSAHS,[14–18] only a subgroup of habitually snoring children have OSAHS.[13]

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Genetic and environmental factors influence snoring, and many studies support an anatomic origin.[19,20] Palatal flutter has been reported to be the most important cause of snoring.[21] In situations of airway obstruction, the blockage is often located at the level of the soft palate, but has also been identified elsewhere within the entire extent of the pharynx.[21–23]

Several studies have used cephalometrics to examine for anatomic differences in snoring and apneic subjects.[19,24–28] Most frequently, cephalometric radiographs of adults with apnea were compared with radiographs of nonapneic adults. The tendency was for apneic adults to have an increased hyoid to mandibular plane (H–MP) distance, longer soft palates, a diminished sagittal cranial base dimension, and narrower posterior airways. Few studies have investigated differences in cephalometric factors in children. A Japanese study[29] found that children with apnea had an inferiorly positioned hyoid. In the most severe apneics, the children presented with enlarged adenoids and narrow airways. An Italian study[30] reported that habitually snoring children with apnea and adenotonsillar hypertrophy had increased craniomandibular intermaxillar, lower and upper gonial angles with a retroposition, and posterior rotation of the mandible (high-angle face), and a reduction in the nasal posterior airway space because of enlarged adenoids. Most previous reports have used a sample of children suspected of having OSAHS, who were referred to either the Sleep Disorders Center or the otolaryngology department. However, there have been no reported cephalometric studies in children with and without habitual snoring conducted in settings such as the orthodontic environment in which predominately healthy children with dental malocclusions are seen at fairly regular intervals. We speculate that such a population affords the feasibility of studying children when they are healthy, presumably before disease development, and as an impetus for future investigations.

The purpose of the present study was to determine the differences in craniofacial factors between habitual snoring and nonsnoring children from an orthodontic population, using measurements made from cephalometric radiographs.

Materials and Methods

Study Sample

The study sample was derived by a two-step process: (1) The first step included screening for children (ages 7 to 14 years) with sleep and behavior problems from a population seeking pretreatment orthodontic evaluation at the School of Dentistry, and from 12 orthodontic private practices in Cleveland, OH. Children who had been treated before this initial examination by means of either orthodontics or dentofacial orthopedics were excluded from the study. This study was approved by the Institutional Review Board of the university. The parents or guardians were asked to sign a consent form and then complete a demographic and sleep behavior questionnaire on behalf of their children. The sleep behavior questionnaire was adapted from a previous study[9] and was administered to parents or guardians of the children for a 10-month period. The questionnaire consisted of 11 Likert-type scale (never, rarely, sometimes, often) and 7 yes/no questions, and has been validated and shown to be reliable in assessing the sleep problems of the child. For the purposes of this study, only the responses to snoring and age at onset of snoring were used. (2) The second step included identifying from the screening questionnaire those children who snored often, with a volume ranging from moderate to very loud. The snoring children (experimental group) were then matched to a control group of nonsnoring children on the basis of age, sex, and ethnicity. The nonsnorers were those children whose parents or guardians had indicated on the questionnaire as having never snored. A total of 31 snoring and 31 nonsnoring children were identified through this process. The pretreatment records of each subject were reviewed to ensure that the child was healthy and free of serious medical problems. Subjects with documented craniofacial anomalies such as cleft lip and palate were excluded. Pretreatment cephalometric radiographs that are part of initial records were examined for diagnostic quality and to ensure that all critical landmarks were included within the boundaries of the image (*eg*, hyoid).

Data Collection

Demographic Data: The subject's sex and ethnicity were documented from the dental records. The height and weight information was obtained from the parents and was recorded for each subject in inches and pounds. The body mass index (BMI) was then calculated for each subject (weight in kilograms/height [meters squared]).

Cephalometric Data: The nasion rest on the cephalometer used to expose the cephalometric radiographs was measured to assist in determining the magnification of the radiographic images. All linear measurements were adjusted for their respective level of magnification. The cephalometric radiographs of the subjects were traced and a total of 11 linear and 1 angular measurements were recorded by a single investigator (R.K.).

Figure 1 illustrates the following five conventional hard-tissue linear measurements and the mandibular plane: the linear measurement from sella turcica to nasion (S–N); the linear measurement from basion to nasion; the anterior-posterior length of the maxilla measured from A-point to the posterior nasal spine (A–PNS); the effective length of the body of the mandible measured from gonion to gnathion (Go–Gn); and H–MP (measured from the most inferior border of the mandible to menton).

Figure 2 illustrates six soft-tissue linear measurements and the occlusal and B-point to gonion reference planes. The measurements include the length of the soft palate; the vertical airway length measured from the posterior nasal spine (PNS) to the base of the epiglottis (VAL); tongue length (TL) measured from the base of the epiglottis to the most anterior point of the tongue that touches the lingual surface of the mandibular incisors; the width of the pharyngeal airway at the most posterior-superior point on the soft palate (S–PAS), measured parallel to the functional occlusal plane from the posterior-superior palate to the superior posterior pharyngeal wall; the width of the pharyngeal airway at the level of the plane from B-point to gonion measured from the inferior posterior pharyngeal wall to the most anterior point in the airway on the tongue; and the width of the pharyngeal airway at its most narrow

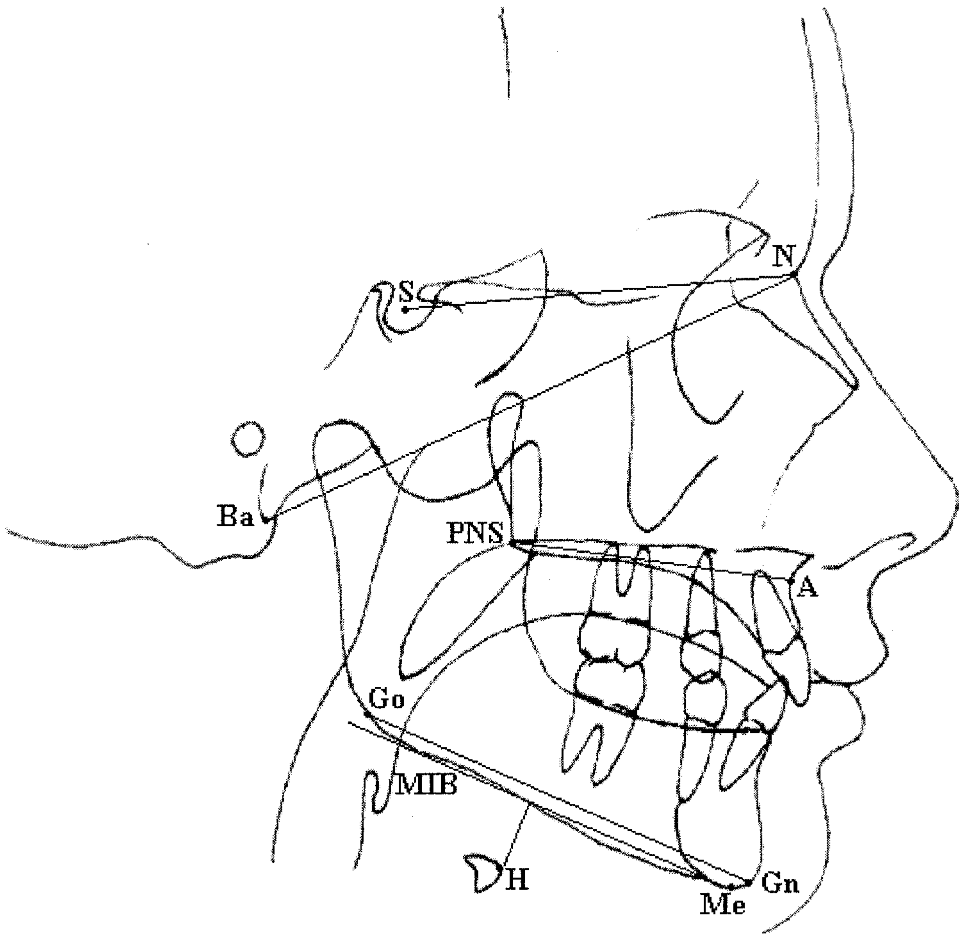

FIGURE 1. Hard-tissue linear measurements and the mandibular plane. Cephalometric landmarks: S = sella turcica; A = A-point, subspinale; Ba = basion; H = hyoidale; Me = menton; Go = gonion; MIB = inferior border of the mandible; N = nasion; Gn = gnathion.

point inferior to the PNS and superior to gonion (N–PAS). It was measured from the posterior pharyngeal wall at the narrowest point to the most anterior point in the airway on the soft palate, parallel to the plane from B-point to gonion.

Figure 3 demonstrates the measure called middle cranial fossa (MCF) alignment, which is taken from the counterpart analysis of Enlow et al.[31] The alignment of the subject's MCF is compared with a neutral position found at 40.3°. The PM is the boundary that separates the anterior cranial fossa and nasomaxillary complex from the middle cranial fossa and pharynx. The PM vertical (patient's PM) is a line from the averaged intersections of the great wings of the sphenoid and anterior cranial floor, extending to the averaged lowermost points of the pterygomaxillary fissure. A subject with a vertical PM located anterior to the neutral position has a forward alignment of the MCF and a protrusively positioned maxilla. The opposite is true for a vertical PM located behind the neutral PM.

Errors in landmark identification were estimated by examining duplicate tracings of 12 of the cephalometric radiographs (19%). Intraclass correlation coefficients[32] were computed to examine the reliability of landmark identification. Intraexaminer reliability for the 12 cephalometric variables ranged from 0.75 to 0.99.

Statistical Analysis

The independent variables measured on a continuous scale included 12 anatomic variables derived from cephalometric radiographs, age, and BMI. Sex was used as a dichotomous variable. Means and SDs were calculated for all continuous variables. Paired Student's t tests were used to test for equality of means between snoring and nonsnoring children. A p value < 0.004 using Bonferroni's correction (α of 0.05 divided by the total number of variables [0.05/12 = 0.004]) was used to determine statistical significance. All computations were performed using the Statistical Package for the Social Sciences (SPSS-PC+ for Windows; SPSS; Chicago, IL).

RESULTS

A total of 228 parents and guardians completed the sleep behavior questionnaire. The parents and guardians were given the option of selecting from the following five choices when asked whether their child snored: never, rarely, sometimes, often, and unsure. Approximately 16% of the children snored often, 20% sometimes, 31% rarely, 32% had never snored, and 1% were unsure. Thirty-six children snored often. However, from a pool of 74 subjects who had never snored, it was only possible to accurately match 31 pairs for age, sex, and ethnicity.

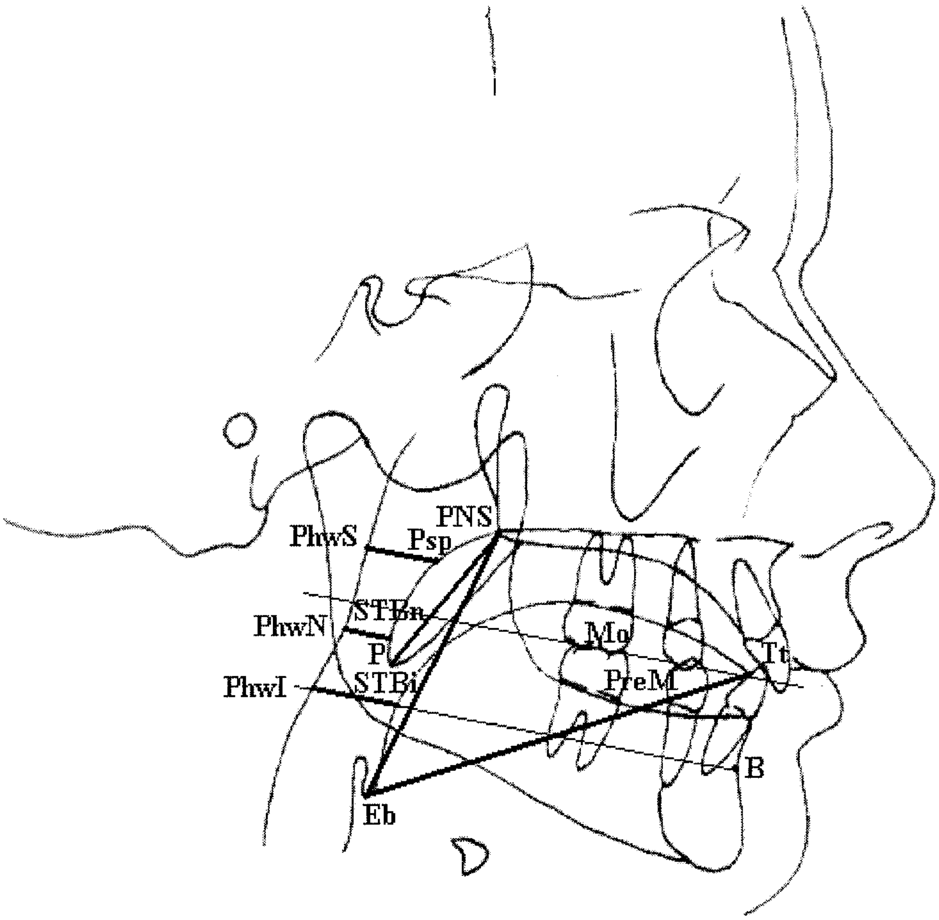

FIGURE 2. Soft-tissue linear measurements and the occlusal and B-point–Go reference planes. Cephalometric landmarks: B = B-point, supramentale; Eb = base of the epiglottis; Mo = molar; P = palate, the most inferior tip of the soft palate; PhwI = inferior posterior pharyngeal wall; PhwN = posterior pharyngeal wall at narrowest point; PhwS = superior posterior pharyngeal wall; PreM = premolar; Psp = posterior-superior palate, the most posterior-superior point of the soft palate; STBi = most anterior point in the airway on the tongue; STBn = most anterior point in the airway on the soft palate; Tt = tip of the tongue. Lines indicate the following measurements: VAL = PNS to Eb; TL = Eb to Tt; S–PAS = PhwS to Psp; N–PAS = PhwN to STBn; I–PAS = PhwI to STBi.

Furthermore, we had to eliminate three experimental children who had adenotonsillectomy before seeking orthodontic care, because of concerns about the treatment's effect on soft-tissue measurements. Hence, the three control children who were matched to these experimental children were also eliminated from the analyses.

The 56 subjects who constituted the study sample were 64% female, 82% white, with a mean age of 10 ± 2 years (range, 7 to 14 years). Tonsils and adenoids were present in all subjects. The BMI was significantly ($p = 0.038$) greater in the snoring group (20.4 ± 4.6) compared with the nonsnoring group (17.9 ± 3.4). The average age of onset of snoring was 34.6 ± 30 months with a range from birth to 9 years.

Comparison of means for the 12 cephalometric variables between the snoring and nonsnoring subjects are presented in Table 1. The variables presenting the most significant difference ($p < 0.004$) between the groups included H–MP, N–PAS, and S–PAS. The measures of VAL, A–PNS, S–N, and Go–Gn demonstrated a trend toward significance ($p < 0.05$) between the snoring and nonsnoring groups.

Discussion

The present study included subjects between the ages of 7 years and 14 years, because that was the age range of most children presenting for orthodontic treatment. Only 36 of 228 subjects (16%) surveyed answered "often" to the snoring question. This percentage is slightly higher than the previously reported

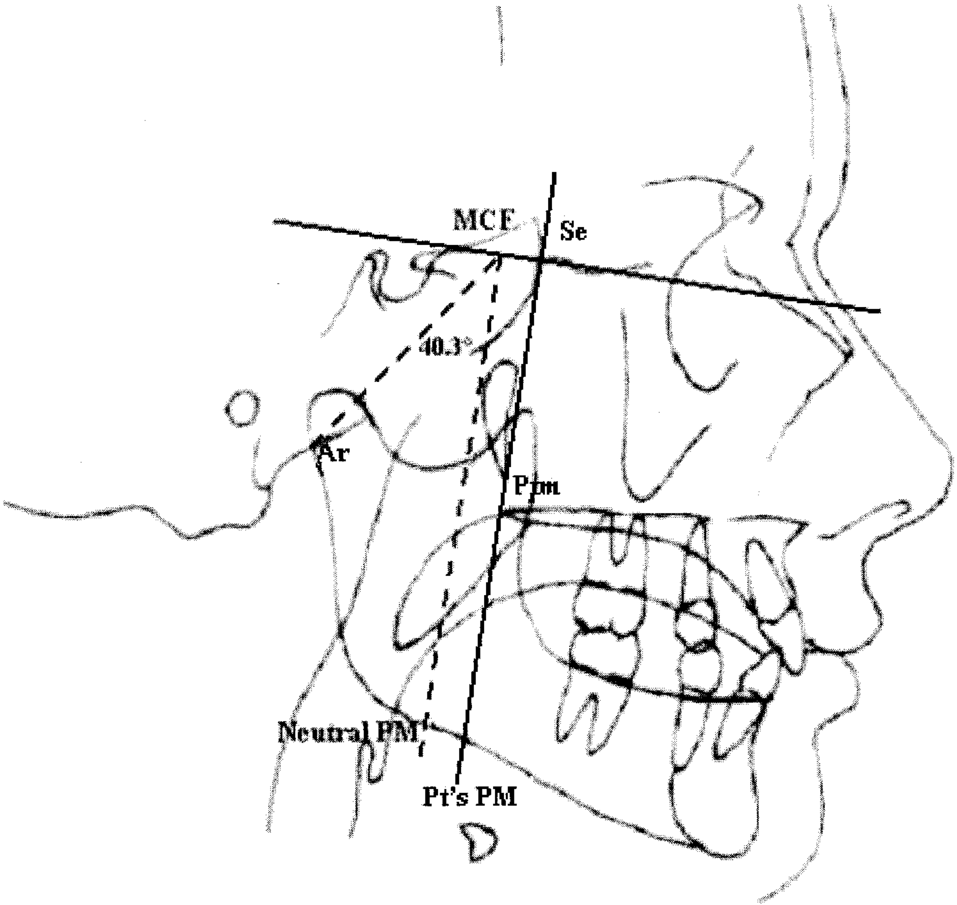

FIGURE 3. MCF component of the counterpart analysis. This diagram demonstrates the effect of a rotational alignment of a subject's own cranial base (patient's PM) compared with the neutral position (neutral PM). A neutral PM (or MCF) is an internal angle of 40.3°. When the patient's PM is anterior to the neutral PM, as shown here, there is forward alignment of the MCF and protrusive maxilla or retrusive mandible. When the patient's PM is posterior to the neutral PM, there is backward alignment of the MCF and retrusive maxilla or protrusive mandible. Ar = articulare; Se = sphenoethmoidal junction; Ptm = pterygomaxillary fissure; Pt's = patient's.

snoring prevalence of 7% to 12% in children.[9–12] One reason for the above-average percentage of snoring children in our study might be attributed to selection bias introduced by an orthodontic practice in gathering the experimental subjects. This private office completed sleep behavior questionnaires on snoring subjects only. The total contribution to the study from that practice consisted of two experimental subjects. Subjects from the dental school clinic and the other private practices were recruited randomly according to the selection criteria.

The average age at onset of snoring in the present study was somewhat higher than the results of Brouillette et al in 1982.[16] They examined > 70 infants and children with OSAHS and found that the mean age at onset of breathing difficulties, including snoring, was 14 ± 12 months. Most of the subjects in their study were < 5 years of age. Our study cannot be compared directly to the study by Brouillette et al[16] because of the fact that their sample comprised young and apneic children. However, indications are that snoring and breathing difficulties can start early in children.

BMI was observed to be significantly greater in snoring children than in nonsnoring children in the present study. We did not directly measure the height and weight of our subjects, but had to depend on the recall of this information from the parents. Whether the parents recalled this information correctly is subject to uncertainty. However, our results are contrary to other studies that have reported that snoring and apneic children may in fact be underweight or underdeveloped.[16,33] In another study of children, no significant differences in obesity were found between primary snoring and apneic children.[13] This finding could have been influenced by

Table 1—*Comparison of Means of Cephalometric Variables Between Snoring and Nonsnoring Subjects**

Variables	Snoring Subjects	Nonsnoring Subjects	p Value
H–MP	16.73 ± 4.05	12.96 ± 5.27	0.002†
P–PNS	30.79 ± 4.25	29.90 ± 3.72	0.421
VAL	58.36 ± 6.77	55.32 ± 7.43	0.042
Ba–N	98.26 ± 6.45	99.92 ± 5.72	0.201
S–N	65.12 ± 3.48	67.12 ± 4.47	0.024
A–PNS	43.36 ± 3.25	45.21 ± 3.05	0.011
TL	70.63 ± 6.03	69.98 ± 6.22	0.720
S–PAS	7.72 ± 3.76	11.99 ± 3.94	0.001†
I–PAS	12.12 ± 3.05	11.68 ± 2.99	0.651
N–PAS	4.84 ± 2.78	8.00 ± 2.53	0.000†
Go–Gn	66.21 ± 5.17	69.34 ± 5.62	0.014
MCF	−0.049 ± 3.29	0.723 ± 2.43	0.310

*Values given as mean ± SD, unless otherwise indicated. Ba–N = linear measurement from basion to nasion; P–PNS = length of soft palate; I–PAS = width of pharyngeal airway at level of the plane from B-point to Go.
†Significant at $p < 0.004$.

the lack of a nonsnoring group for comparison. In addition, there are conflicting reports from the adult literature, inasmuch as some studies have found BMI to be significantly increased in snoring and apneic populations,[24–26,28] whereas others have found BMI to be of no significance in adults.[27,34]

We chose 12 cephalometric variables based on their importance as reported in the literature[35] and our previous studies.[36,37] In comparing the means of these 12 cephalometric measurements, three variables demonstrated statistical significance. H–MP distance was significantly longer in snoring children. The normative values for H–MP distance for normal healthy children (ages 10 to 17 years) with no sleep problems ranged between 14.8 mm and 15.9 mm.[38] Although our sample of children were younger, the snorers had a larger vertical distance (17 mm) than the normal values. Apneic children have also been found to have an increased H–MP distance.[29] In studies of apneic adults, the H–MP distance was consistently associated with OSAHS.[35] In a recent study,[39] the relationship between oropharyngeal airway (OPA) and hyoid position has been described as when the mandibular body lengthens, the attachments of the genioglossus and geniohyoid muscles move forward away from the oropharynx, thus increasing the OPA. Also, this study strongly supports an association between a short mandible and small OPA in the context of OSAHS. Also, in our present study, we found the snoring children to have a strong tendency toward a smaller mandibular length compared with that of nonsnorers. Whether children with only primary snoring and no apnea, but with smaller mandibular length and inferiorly positioned hyoid, eventually develop OSAHS in later years is an area worth investigating with longitudinal studies.

Two of the three measures of pharyngeal width (S–PAS and N–PAS) also showed statistical significance in the present study. Previous studies have also found significant reduction in posterior airway space in apneic children, and attributed the narrowing of the airway to tonsil and adenoid hypertrophy, and anatomic abnormalities.[16,29,39] In the present study, a greater proportion of the parents of snoring subjects were told by the physician that the children had enlarged adenoids (38% vs 7%) and tonsillar hypertrophy (32% vs 13%). This may in part have contributed to the pharyngeal narrowing in the snoring children. However, caution has to be exercised with the reporting of the adenotonsillar hypertrophy, as a clinician did not conduct intraoral examinations on these children at the time of this study. Furthermore, we could not analyze the results separately for those with and without adenotonsillar hypertrophy because our sample sizes were small; therefore, stratification would have meant less precise results.

The present study found an increase in the VAL, and a shortened maxilla (A–PNS) and cranial base (S–N) in snoring subjects. Pae et al[40] suggest that an extended airway results in narrowing and turbulent airflow. Others have observed neck extension to act favorably on nasorespiratory function.[41,42] The fact that snorers had a shortened maxilla (A–PNS) and cranial base (S–N) may suggest a narrowing in the sagittal dimension. In a recent study of habitually snoring and apneic children, the authors suggest that retroposition of the mandible was not essential to the development of upper-airway obstruction, but rather contributed by posterior crossbites caused by a reduced growth of the maxilla after continuous oral breathing, and anterior open-bite with lip incompetence, owing to a forward tongue position.[30] Studies in adults have also demonstrated a significant reduction in the sagittal dimension of the anterior cranial base in apneics,[19] a reduction in cranial base and mandible in snorers, and a shorter maxilla in apneics.[25] These studies suggest that habitual snorers might have an anatomic predisposition to airway obstruction.

A limitation of the present study is that we did not evaluate the children with polysomnography to determine the degree of respiratory disturbances during sleep. Therefore, some of the snoring children may have had apneas. But according to a previous study, only a subgroup of habitually snoring children have apneas.[13] We speculate that many of our children may have been just primary snorers, especially because the children were healthy and were not referred to us because of suspected OSAHS. Although this cross-sectional study is limited in helping us understand whether anatomic variation exists from childhood, our data suggest that there are craniofacial factors that may be different between snoring and nonsnoring children. Approximately 90% of the growth of the craniofacial skeleton is obtained by the age of 12 years, and 60% by the age of 4 years.[43] Inasmuch as the average age of the present study population was 10 years, we can assume that facial growth and development might have already been modified, especially in the presence of airway obstruction early in life. Therefore, future studies should consider studying children before the age of 4 years to understand whether craniofacial factors precede the development of OSAHS.

Other methodologic limitations of the study include the following:

1. Sample size was limited by the number of experimental subjects that met the criteria of the study. As with most studies, a larger sample may have demonstrated greater precision of the results. Also, selection bias could have affected the study results, inasmuch as only subjects seeking orthodontic treatment were included. Our subjects were undergoing orthodontic treatment for the correction of dental anomalies. We excluded children with craniofacial anomalies, and therefore craniofacial factors that do differ between our sample and children who do not seek orthodontic treatment are probably minimal. However, it is also more prevalent for middle and higher socioeconomic groups to seek orthodontic treatment than the lower-income groups. Therefore, generalization to a larger population is still limited.
2. The cephalometric radiographs used in the study came from multiple sources. The radiographs were all exposed on cephalometers incorporating ear rods and nasion rests to approximate the Frankfort horizontal plane parallel to the floor. Although radiographic quality could be controlled, head position was not controlled for during exposure. A prior study[44] had noted that a change from natural head position to a 20° extension resulted in a change in hyoid position and increased cross-sectional dimension of the retroglossal pharynx. Future studies should control for the head position.
3. Owing to uncontrolled upper-airway muscle activities, the measurements of posterior airway space may not always be reliable. Many of the soft-tissue points used in this study are subject to variation in landmark identification, but repeat measurements indicated that the reproducibility of these variables were good.
4. The use of cephalometric radiographs provides only a static two-dimensional image in the sagittal plane. Inferences to three-dimensional anatomic structures cannot be made based solely on the cephalometric image. Additionally there could be differences between upright and supine radiographs. Findings by our group[36] indicated that upright evaluation provided the same information as supine, and that group differences in airway morphology can be detected using standard cephalometric radiography in the upright position.

Conclusion

The value of the cephalometric radiograph in the study of the head and neck and associated pathologies is unsurpassed. It is widely accessible and relatively inexpensive in comparison to alternative imaging procedures. Information obtained from cephalometric assessment has been invaluable in a great number of studies in airway pathology, including snoring and sleep apnea.

Our data indicate that there are craniofacial differences between snoring and nonsnoring children. Longitudinal studies of habitually snoring children without apnea could demonstrate whether craniofacial modification is an effect of airway obstruction or genetically determined, and whether these children do eventually develop OSAHS in the ensuing years.

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