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SCIENTIFIC INVESTIGATIONS

Oropharyngeal Dimensions in Adults: Effect of Ethnicity, Gender, and Sleep Apnea

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Study Objectives: This study sought to (1) investigate ethnic and gender differences in oropharyngeal dimensions in subjects with and without sleep disordered breathing (SDB) and (2) assess the utility of novel pharyngometric measures in the evaluation of the upper airway.

Methods: Demographic, anthropomorphic, and sleep-related information were collected from 210 subjects enrolled in a genetic-epidemiology study of SDB via standard questionnaires, direct measurement, and polysomnography. Oropharyngeal dimensions were assessed with acoustic pharyngometry using standard and novel measures.

Results: Mean and minimum cross-sectional areas (CSA) were smaller in Whites and Blacks with SDB compared to unaffected individuals of the same ethnicity. Unaffected Blacks had smaller mean and minimum CSA compared to unaffected Whites. No difference in either parameter was detected between Blacks without SDB and Whites with SDB. Neither parameter varied with SDB status in women, but both were smaller in men with SDB compared to unaffected men. Analysis of novel parameters suggested that differences in upper airway anatomy in Whites and Blacks with SDB were focused in the proximal and distal oropharynx, respectively.

Conclusions: Acoustic reflectometry demonstrates differences in the relationship of oropharyngeal dimensions and SDB status according to gender and ethnicity. Novel pharyngometric parameters assist in elucidating these differences.

Keywords: Acoustic reflectometry, ethnicity, gender, oropharynx, sleep disordered breathing

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The propensity for developing SDB is influenced by demographic characteristics including ethnicity[1,2] and gender,[3] as well as morphologic factors, such as oropharyngeal anatomy.[4,5] The increased prevalence of SDB in men[3] and Blacks,[2] coupled with the link between smaller oropharyngeal dimensions and SDB,[4,5] suggests the need for further investigation aimed at discerning whether variation of anatomic risk factors among population subgroups plays a role in the observed ethnic and gender differences in SDB.

Commentary Follows on Pages 264-265

Among the techniques used in the assessment of oropharyngeal anatomy, the advantages of acoustic pharyngometry stem from its ease of use, non-invasive nature, portability, and low cost in comparison to other methods such as magnetic resonance imaging or catheter-based methods.[5,6] Prior studies using pharyngometry have relied on the standard measures of mean and minimum cross-sectional area (CSA) without regard to the location of the extreme values of CSA or consideration of the variation in airway caliber over the length of the oropharynx. We postulate that quantification of these characteristics, derived using acoustic pharyngometry, may provide additional information over that obtained using traditional pharyngometry measurements, and thereby may improve the characterization of anatomic risk factors for SDB among population sub-groups.

Using demographic, anthropomorphic, polysomnographic, and pharyngometric data collected as part of the Cleveland Family Study, a longitudinal investigation of SDB in an urban population, we sought to investigate further the relationship between epidemiological and anatomic risk factors for SDB through (1) the use of established acoustic methods to quantify differences in upper airway anatomy based on ethnicity, gender, and SDB status and (2) development and application of novel parameters derived from pharyngometry waveforms.

METHODS

Study Sample and Data Acquisition

The Cleveland Family Study is a cohort assembled to study the genetic-epidemiology of SDB and is comprised of subjects with SDB, their family members, and neighborhood control families. The details of recruitment and clinical evaluation have been described elsewhere.[3,7,8] Participants have been studied up to four times over a thirteen year period. Subjects participating in the current exam, which involved intensive phenotype characterization, were selected based on genetic informativity for SDB, and included a disproportionate number of individuals with SDB.[7]

Disclosure Statement

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Approximately 90% of the individuals in the current report were included in previous reports of SDB risk factors.[3,7]

Participants were studied in the General Clinical Research Center, where they were admitted for an overnight sleep study, with a large variety of phenotypic data collected prior to discharge the following afternoon. The polysomnography recording consisted of two electroencephalograms, bilateral electrooculograms, a bipolar submental electromyogram, thoracic and abdominal respiratory inductance plethysmography, airflow (by a nasal-oral thermocouple and nasal pressure recording), finger pulse oximetry, electrocardiogram, body position, and bilateral leg movements (Compumedics E Series, Abbotsville, AU). Studies were scored by certified research technologists. Apneas and hypopneas were defined using Sleep Heart Health Study criteria, modified to include consideration of the nasal pressure signal.[9] Respiratory events were identified as a clear, discernible (> 30%) decline in airflow (from the thermocouple or nasal pressure signals) or respiratory effort (from inductive respiratory bands) for ≥ 10 seconds associated with an oxygen desaturation of ≥ 3%. The apnea-hypopnea index (AHI) was defined as the mean number of respiratory events per hour of sleep. Other data included bioelectric impedance (for estimating body fat), as well as assessment of symptoms of SDB with a standard questionnaire.[10]

Standard Pharyngometry Measurements

Pharyngometry data were collected within one day of the sleep study, using the EcoVision Acoustic Pharyngometer (E. Benson Hood Laboratories, Pembroke, MA). A prototype of this system has been used previously in adults to measure pharyngeal CSA.[4,6,11-13] Each measurement consists of a plot of CSA (cm^2) as a function of distance (cm) from the oral cavity. Estimates of mean and minimal pharyngeal CSA are derived using proprietary software. Oropharyngeal length is defined as the distance between the oropharyngeal junction and the epiglottis. Similar to our previous study,[5] for each subject, a baseline curve was obtained using nasal breathing. Subsequent measurements were obtained using oral breathing at functional residual capacity, while subjects were awake and in the sitting position. Attempts were made to obtain three 'high quality' curves that exhibited characteristics seen on a reference diagram,[5] namely a well-defined oral cavity segment between 0-5 cm, a distinct oropharyngeal segment, and no evidence of tongue occlusion or leak. Restricting the analysis to adults (≥ 18 years of age) that produced at least two 'high quality' curves yielded a total analytic sample of 210 subjects.

Development of Novel Pharyngometry Parameters

Figure 1 shows a sample pharyngometry curve labeled with features that can be used as additional descriptors of oropharyngeal anatomy. A standard reference diagram that displays the corresponding anatomical landmarks has been published elsewhere.[5] The maximum CSA serves as the reference point for parameter development. Calculation of the fractional distances along the oropharynx at which extreme values of CSA occur facilitates direct comparison between subjects, accounting for variability in oropharyngeal lengths. The proximal minimum refers to the lowest CSA value prior to the maximum, and the distal minimum refers to the lowest CSA value that occurs after the maximum is reached. Correspondingly, the proximal and distal slopes are defined as the rates of change in CSA between the proximal minimum and maximum CSA and the maximum CSA and distal minimum, respectively. Likewise, the fractional increase and decrease are the relative amounts that the CSA has changed between the respective minimum and the maximum CSA. The maximum negative slope, and the fractional oropharyngeal distance at which it occurs, allow for detection of significant changes in airway caliber that do not necessarily involve the extreme values of CSA. These measures were calculated for each subject from each of their 'high quality' curves and then averaged to produce representative values for each individual. Coefficients of variation (CV) for the novel parameters ranged from 5-15% with slope-related variables having higher CVs than those of non-slope-related variables. CVs for standard parameters were 5% for mean CSA and 7% for minimum CSA, which are comparable to our previous data in children[5] and standard reference values for adults.[11]

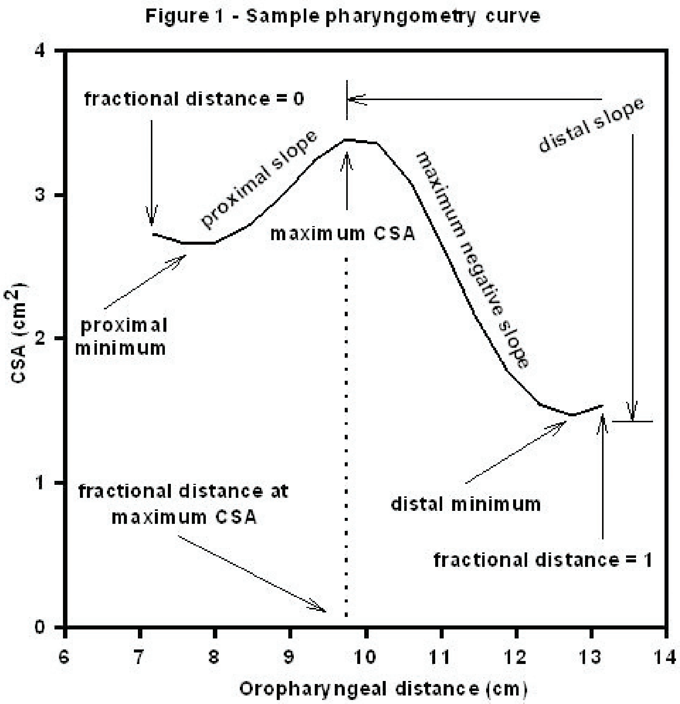

Figure 1—The fractional distance at maximum cross-sectional area (CSA) is the fraction along the oropharyngeal length that the maximum CSA occurs. The proximal minimum is the local minimum CSA that occurs before the maximum CSA is reached. Similarly, the distal minimum is the local minimum CSA that occurs after the maximum CSA is reached. The proximal slope is the average rate of CSA change between the proximal minimum and the maximum CSA. Likewise, the distal slope is the average rate of CSA change between the maximum CSA and distal minimum. The maximum negative slope is the maximal rate of CSA decline. Additional terms not noted on the diagram include the fractional distances along the oropharynx of the proximal and distal minima as well as the maximum negative slope, and the fractional increase/decrease in CSA, which represent the relative change in CSA between the maximum and the corresponding local minima.

Definitions and Statistical Analysis

SDB was defined in an age-related fashion based on AHI: ≥ 5 events/hour for ages 18 to 25 years; ≥ 10 events/hour for age 25-50 years; ≥ 15 events/hour for age > 50 years. For subjects between the ages of 18-21, obesity was defined as a BMI (body mass index) ≥ 95th percentile for age and gender. For subjects

Table 1A—Population Characteristics by Ethnicity and SDB

	White			Black		
Characteristic	**No SDB (n=75)**	**SDB (n=32)**	**p value**	**No SDB (n=62)**	**SDB (n=41)**	**p value**
Age ± SE (years)	50.4 ± 2.1	48.2 ± 3.0	0.52	41.8 ± 2.2*	43.3 ± 2.6	0.64
Gender (% male)	48.0	62.5	0.17	37.1	65.9	0.004
BMI ± SE (kg/m^2)	32.4 ± 1.4	36.8 ± 1.9	0.04	34.1 ± 1.5	36.9 ± 1.7	0.18
Body fat ± SE (%)	34.0 ± 1.0	38.6 ± 1.4	0.007	35.8 ± 1.1	39.0 ± 1.3	0.049
Obesity (%)	52.0	81.2	0.003	53.2	82.9	0.001
Habitual snoring (%)	37.1	59.3	0.053	26.9	68.4	<0.0001
AHI ± SE (events/hour)	5.2 ± 2.3	37.1 ± 3.2	<0.0001	5.4 ± 2.5	31.0 ± 2.8	<0.0001

*$p < 0.01$ for comparison to Whites without SDB
AHI: apnea-hypopnea index; BMI: body mass index; SE: standard error; SDB: sleep disordered breathing
Note: SDB defined by age adjusted threshold values of AHI (see Methods section)

Table 1B—Population Characteristics by Gender and SDB

	Female			Male		
Characteristic	**No SDB (n=78)**	**SDB (n=26)**	**p value**	**No SDB (n=59)**	**SDB (n=47)**	**p value**
Age ± SE (years)	44.7 ± 15.5	45.5 ± 15.6	0.83	46.9 ± 18.4	45.2 ± 15.3	0.60
Ethnicity (% EA)	50.0	46.2	0.74	61.0	42.6	0.06
BMI ± SE (kg/m^2)	33.7 ± 1.2	36.9 ± 1.9	0.13	32.7 ± 1.3	36.5 ± 1.5	0.046
Body fat ± SE (%)	45.2 ± 0.9	50.3 ± 1.5	0.004	24.9 ± 1.0*	28.0 ± 1.1*	0.04
Obesity (%)	53.9	73.1	0.09	50.9	87.2	<0.0001
Habitual snoring (%)	30.7	58.3	0.02	34.6	68.3	0.001
AHI ± SE (events/hour)	4.5 ± 2.1	24.9 ± 3.2	<0.0001	5.1 ± 2.3	39.7 ± 2.5*	<0.0001

*$p < 0.0003$ for comparison to females of similar SDB status
AHI: apnea-hypopnea index; BMI: body mass index; EA: European-American; SE: standard error; SDB: sleep disordered breathing
Note: SDB defined by age adjusted threshold values of AHI (see Methods section)

greater than 21 years of age, obesity was defined as a BMI ≥ 30 kg/m^2.

Comparisons of subject characteristics (age, gender, and BMI), and standard and novel pharyngometry parameters were analyzed using methods for clustered data. Since the 210 subjects came from 74 families, we accounted for the intra-family correlation using two regression techniques. Continuous measurements were compared with a mixed linear model using maximum likelihood estimation as implemented in SAS Proc Mixed (SAS version 8.2; SAS Institute Inc, Cary, NC). The covariance structure of the multivariate response was modeled with an exchangeable matrix. Binary measurements were modeled using a generalized estimating equation model with the logit link and an exchangeable covariance matrix. All models included age, gender, ethnicity, and SDB status. To allow for model estimation and testing across ethnic/SDB and gender/SDB subgroups, the interactions between SDB and ethnicity and SDB and gender were included in the corresponding models. Pearson's correlation coefficients were estimated to assess the association between the various standard and novel parameters. Inferential tests were performed using the nonparametric bootstrap test and 95% confidence intervals were computed using the basic bootstrap confidence limits.[14]

RESULTS

Population Characteristics

Subject demographics and traditional risk factors for SDB stratified by ethnicity and gender are provided in Table 1 (panel A for ethnicity and panel B for gender). Slightly less than one-half (48%) of the subjects were Black and slightly more than one-half (51%) were women. SDB was more prevalent in Blacks (40%) than in Whites (30%), and in men (56%) than in women (25%). In analyses stratified by ethnicity or gender, there were no age differences among those with SDB compared to those without SDB. As expected, indices of obesity were higher among SDB than non-SDB groups. When compared to unaffected individuals, male subjects with SDB were more likely to be Black, although there was no such ethnic pattern among females. A comparison of the analytic sample with subjects that were excluded due to insufficient 'high quality' pharyngometry data (n = 74) showed no differences in demographic or anthropometric characteristics between the groups.

Variation of Standard Pharyngometry Measures With SDB and Ethnicity

Table 2 (top) provides the age and gender-adjusted distributions of pharyngometry measures among ethnic and SDB subgroups. For both ethnic groups, the standard measures of mean and minimum CSA are reduced in those with SDB relative to those without SDB, although differences in minimum CSA are of marginal significance for Blacks. In subjects without SDB, both measures are reduced in Blacks compared to Whites. There are no significant differences in either measure between Blacks without SDB and Whites with SDB ($p = 0.85$ for mean CSA; $p = 0.34$ for minimum CSA). Oropharyngeal length (expressed as an absolute dimension or normalized to the subjects' height) is reduced in Blacks, but not Whites, with SDB compared to unaffected individuals. Additionally, among subjects with SDB, Blacks had a shorter oropharyngeal length than Whites.

Table 2— Variation in Pharyngometric Dimensions, Adjusted for Age and Gender, by Ethnicity and SDB

	White		Black		p Values for Comparison			
Characteristic	**No SDB (n=75)**	**SDB (n=32)**	**No SDB (n=62)**	**SDB (n=41)**	**W/no SDB W/SDB**	**B/no SDB W/no SDB**	**B/SDB B/no SDB**	**W/SDB B/SDB**
Standard parameters								
Mean CSA (cm^2)	2.74 ± 0.07	2.40 ± 0.11	2.42 ± 0.08	2.10 ± 0.10	0.02	0.02	0.008	0.06
Minimum CSA (cm^2)	1.91 ± 0.06	1.59 ± 0.09	1.69 ± 0.06	1.51 ± 0.08	0.004	0.08	0.01	0.51
OP length	6.55 ± 0.22	6.71 ± 0.30	6.44 ± 0.24	5.62 ± 0.27	0.64	0.02	0.75	0.01
OP length/height	0.038 ± 0.001	0.040 ± 0.002	0.038 ± 0.001	0.033 ± 0.002	0.48	0.02	0.79	0.008
Novel parameters								
Maximum CSA (cm^2)	3.81 ± 0.08	3.53 ± 0.13	3.27 ± 0.11	2.79 ± 0.15	0.14	0.02	0.0004	0.0007
Fractional distance of MaxCSA	0.48 ± 0.04	0.66 ± 0.05	0.60 ± 0.04	0.54 ± 0.05	0.008	0.38	0.04	0.13
Proximal minimum CSA (cm^2)	2.42 ± 0.11	1.92 ± 0.17	1.95 ± 0.13	2.01 ± 0.15	0.02	0.80	0.008	0.71
Fractional distance ProxMinCSA	0.06 ± 0.02	0.12 ± 0.02	0.09 ± 0.02	0.12 ± 0.02	0.02	0.19	0.30	0.96
Distal minimum CSA (cm^2)	2.23 ± 0.12	2.48 ± 0.16	2.56 ± 0.12	2.00 ± 0.14	0.17	0.002	0.07	0.03
Fractional distance DistMinCSA	0.92 ± 0.02	0.94 ± 0.03	0.90 ± 0.02	0.90 ± 0.02	0.72	0.97	0.36	0.30

Values are mean ± SE

B: Black; OP: oropharyngeal; CSA: cross-sectional area; Prox: proximal; Dist: distal; SDB: sleep-disordered breathing; Min: minimum; W: White

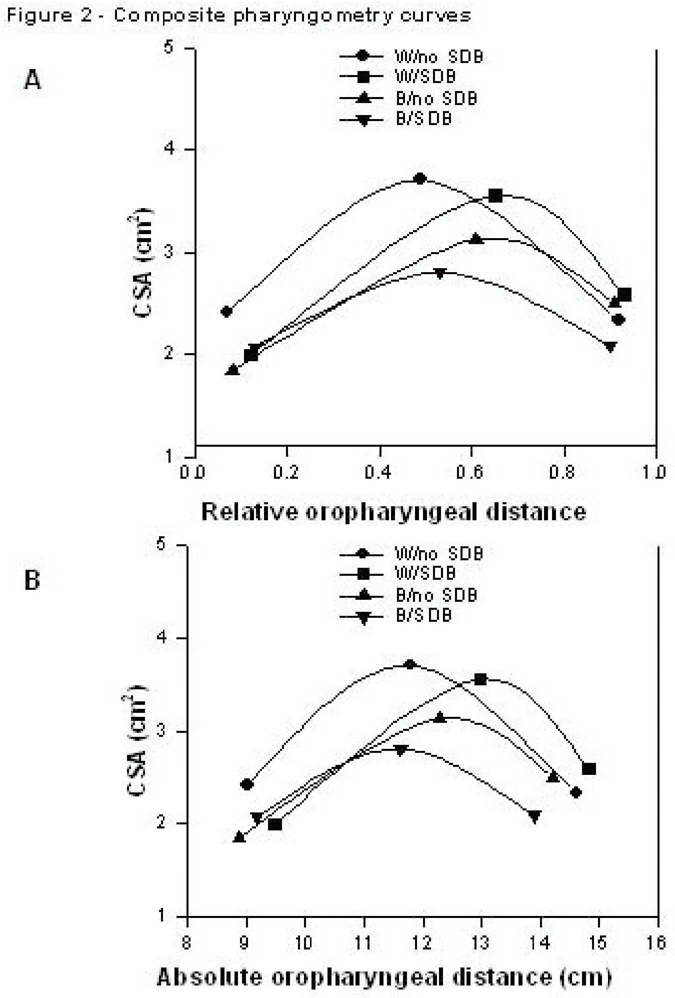

Figure 2—For each ethnicity/sleep-disordered breathing (SDB) group, the average proximal minimum, maximum, and distal minimum cross-sectional area (CSA) (symbols) are plotted as a function of relative (panel A) and absolute (panel B) oropharyngeal distance. The differences in oropharyngeal length among sub-groups are more apparent in the latter panel.

Variation of Standard Pharyngometry Measures With SDB and Gender

The age and ethnicity-adjusted distributions of standard pharyngometry measures among gender and SDB sub-groups are shown in Table 3. Among subjects without SDB, men had larger mean and minimum CSA than women. A difference in those parameters was not apparent when comparing men and women with SDB. In gender-stratified analyses, both mean and minimum CSA were smaller in subjects with SDB, with significant differences seen in men. Significant differences in oropharyngeal length by SDB status was not observed for either gender group.

Novel Pharyngometry Measures

Novel parameters derived from a standard pharyngometry curve, illustrated in Figure 1, are shown for each ethnic/SDB group in Table 2 (bottom). These parameters are based partially on rates of change of CSA, rather than entirely static summary measures such as the mean and minimum. In Whites, the fractional distance at which the maximum CSA occurs is greater (occurs more distally) and the proximal minimum CSA (located ~10-15% along the length of the oropharynx) is smaller in those with, as compared to those without, SDB. Neither of these differences holds in Blacks, although there are some notable variations in the novel variables in that group as well. Namely, compared to Blacks without SDB, maximum CSA and the distal minimum CSA (located ~ 90% along the oropharynx) are significantly smaller in Blacks with SDB than without SDB. Thus, differences in minimum CSA are seen in both ethnic groups, but occur proximally in Whites and distally in Blacks. As was the case with the static parameters, there are no significant differences in any of the novel variables between Blacks without SDB and Whites with SDB. The composite curves shown in Figure 2 further illustrate the differences in oropharyngeal shape within the various ethnicity/SDB subgroups. There were no distinguishing differences in the slopes or other fractional parameters between subgroups. There were no intra-gender or inter-gender differences in the novel parameters, regardless of SDB status.

Table 3— Variation in Pharyngometric Dimensions, Adjusted for Age and Gender, by Ethnicity and SDB

Characteristic	White		Black		p Values for Comparison			
	No SDB (n=78)	SDB (n=26)	No SDB (n=59)	SDB (n=47)	F/no SDB F/SDB	M/no SDB M/no SDB	F/SDB M/no SDB	F/SDB M/SDB
Standard parameters								
Mean CSA (cm^2)	2.34 ± 0.07	2.15 ± 0.12	2.83 ± 0.08	2.40 ± 0.09	0.18	0.001	<0.0001	0.11
Minimum CSA (cm^2)	1.64 ± 0.06	1.46 ± 0.10	1.97 ± 0.07	1.66 ± 0.07	0.13	0.003	0.0003	0.11
OP length (cm)	6.48 ± 0.20	6.33 ± 0.32	6.51 ± 0.22	6.02 0.24	0.68	0.12	0.90	0.42
OP length/height	0.040 ± 0.001	0.039 ± 0.002	0.037 ± 0.001	0.034 ± 0.001	0.70	0.18	0.07	0.05

Values are mean ± SE

CSA: cross-sectional area; F: female; M: male; OP: oropharnygeal; SDB: sleep disordered breathing; SE: standard error

Relationship Between Standard and Novel Parameters

A larger mean CSA was modestly associated with greater oropharyngeal length ($r = 0.22$; $p = 0.009$), and with larger proximal, distal, and maximum negative slopes ($r = 0.43$; 0.27-0.56, $p < 0.001$, $r = 0.38$; 0.24-0.50, $p < 0.001$, $r = 0.34$; 0.28-0.52, $p < 0.001$).

DISCUSSION

Ethnic Differences in Standard Pharyngometry Parameters

Using a relatively simple and non-invasive technique, we demonstrated that individuals with SDB had reduced pharyngeal dimensions, regardless of ethnicity, compared to their age and gender-matched counterparts without SDB. These observations are consistent with pathophysiological models of SDB that have identified reduced airway caliber as a contributor to the predisposition for SDB. Our findings also suggest the potential importance of airway dimensions as differential risk factors for SDB between Whites and Blacks. In this regard, assessment of pharyngeal dimensions may complement analysis of craniofacial morphology, such as assessments made by two-dimensional cephalometry, which has identified hard tissue factors that discriminate SDB status in Whites, but not Blacks.[15] Additionally, the similarity in the standard pharyngometry parameters of CSA between Blacks without SDB and Whites with SDB raises the possibility that, in adults, for any given CSA, the upper airways of Whites may be more collapsible than those of Blacks. The differences in collapsibility may be due to ethnic variation in one or more of the following: neuromuscular conditions that influence airway patency, sites of airway narrowing (as suggested by the novel parameters), length of the oropharynx, and/or other anatomic features that are not readily apparent on pharyngometric assessment.

Gender Differences in Standard Pharyngometry Parameters

Overall, the women in this study had a lower prevalence of SDB and less severe SDB than the men. However, the airway dimensions of women were smaller than those of men, and in women, airway dimensions did not vary significantly by SDB status. In contrast, the decreased airway dimensions in men with SDB compared to unaffected men are consistent with previous studies using the acoustic reflection technique.[16] These observations, coupled with the observed smaller pharyngeal caliber in unaffected women compared to unaffected men suggest that differences in absolute mean or minimum CSA do not explain the increased prevalence of SDB in men relative to women. These findings point to the potential role of other factors that either stabilize the relatively smaller female airway or compromise the patency of the relatively larger male airway. Using small samples of unaffected individuals, several studies have examined gender differences in airway collapsibility by utilizing resistance loading[17] and measurement of critical closing pressure.[18] The former concluded that men had increased upper airway collapsibility while the latter detected no gender difference in collapsibility. Additional mechanisms that are independent of pharyngeal size may explain gender differences in SDB; these include the influence of estrogen and other sex hormones[19-21] and the role of pharyngeal muscle activity.[6] Further work that compares the relative contribution of these mechanisms to gender differences in airway collapsibility may provide important insights into the pathogenesis of SDB.

Novel Pharyngometric Parameters and Ethnic Differences in Airway Anatomy

Analysis of the oropharyngeal shapes of Blacks and Whites, as quantified by the novel pharyngeal parameters and as illustrated in Figure 2, demonstrates differences in how airway dimensions vary in SDB according to ethnicity. The changes in Whites with SDB compared to those of similar ethnicity without SDB appear to be focused in, but not confined to, the proximal oropharynx. Correspondingly, the differences in affected Blacks occur more frequently in the distal airway. Previous studies[12] have postulated that acoustic pharyngometry curves vary in shape according to site of airway obstruction. Given our findings that, in those with SDB compared to those without SDB, a significant reduction in airway caliber occurred proximally in Whites, but occurred distally in Blacks, it follows that the site of obstruction in SDB may vary with ethnicity as well. Whites may have important focal narrowing more proximally whereas in Blacks, the key area of constriction may be more distal (perhaps associated with tonsillar lymphoid tissue or posterior pharyngeal wall narrowing).

The Role of Oropharyngeal Length

The significance of the shorter oropharyngeal length in Blacks with SDB relative to those without SDB remains unclear. There exists a paucity of studies that have examined ethnic differences in oropharyngeal length. However, a prior study that investigated the contribution of airway length to the propensity for pharyngeal collapse in unaffected or minimally affected individuals concluded that the observed male predisposition for collapse was due primarily to an increased length of vulnerable airway.[22] In our cohort, regardless of SDB status, we did not observe a significant gender-based difference in oropharyngeal length, although there was a trend towards reduced length in affected individuals of both ethnicities. In a structure whose caliber both increases and decreases over its length, such as the oropharynx, the net contribution of length to the overall resistance is less well defined than for the case of a uniform CSA. While a shorter airway would be expected to contribute to less of a pressure gradient over the entire length of a uniform airway, the resistance per unit length, which in a simplified model of the CSA as perfectly circular, depends locally on the inverse of the radius to the fourth power, may be a more important determinant of intraluminal pressure and thus a more representative metric for assessing the potential for upper airway collapse. In those with SDB, the contribution to airway resistance of reduced CSA may overwhelm the relative benefit of a shorter airway.

Potential Clinical Implications

This study utilizes non-invasive techniques to study ethnic and gender differences in oropharyngeal anatomy in adults with and without SDB. Using a combination of standard and novel measures derived from the acoustic waveform, we present data that suggest that the site of obstruction in SDB may vary with ethnicity. Our findings also add to the debate regarding the roles of gender and airway length in pharyngeal collapse. While sophisticated MRI analysis may be the ideal modality for phenotyping the upper airway, research protocols involving MRI have been limited to small numbers of patients that preclude subgroup analyses.[23,24] The applicability of MRI to office-based assessment of SDB risk is further limited by availability and cost. Given the subgroup differences demonstrated in the current study, and the reasonable potential for implementation of acoustic pharyngometry in a clinical setting, further analysis of pharyngometric parameters in refining SDB risk profiles appears reasonable. Furthermore, studies that compare measures obtainable with both modalities would provide further information regarding the accuracy of the pharyngometric technique.

Strengths and Limitations

A strength of this study is the inclusion of an ethnically diverse, mixed gender sample with a wide spectrum of SDB, all of whom underwent rigorous, standardized polysomnography and anthropometric measurements. However, since our data are derived from a cohort assembled to study the genetic-epidemiology of SDB, the findings may be most relevant to studies of risk factors among high risk families (with high BMI) and may be less generalizable to a random sample. Nonetheless, the mean CSAs we observed are similar, albeit somewhat smaller than, those found in a previous study of a less obese sample with fewer Blacks and habitual snorers.[11] The current study does not account for the effects of posture on airway caliber, as all measurements were made in the seated position. However, prior studies using cephalometric measures showed no postural variation in the relationship between craniofacial morphology and SDB.[25] Similar analyses using acoustic reflectance found that, compared to unaffected individuals, those with SDB have smaller airways while upright but smaller decrements in caliber when supine, suggesting a more active defense of the airway against collapse in SDB.[26] Thus, reflectometry performed in the seated position may even elucidate useful differences in airway dimensions that dissipate with recumbency. Finally, although our findings suggest the potential utility of both standard and novel pharygometry parameters in phenotyping large populations and identifying differences in oropharyngeal dimensions in population subgroups, future work (such as correlation with MRI) is needed to define the precise anatomic correlates of the standard and novel pharyngometry parameters.

CONCLUSIONS

We conclude that (1) acoustic pharyngometry identifies differences in upper airway characteristics based on gender, ethnicity, and SDB status and (2) novel parameters can assist in quantifying these pharyngeal phenotypes. The novel parameters can potentially facilitate quantitative, as an adjunct to qualitative,[12] comparison of acoustic waveforms. Such analysis may be useful in further establishing risk for SDB, in the assessment of candidacy for various modalities of treatment, for more robust phenotypic analysis in genetic epidemiological studies, and to gauge the response to treatment. Furthermore, although our data provide additional evidence that reduction in airway caliber plays a role in SDB, the relatively small pharyngeal dimensions in women and African Americans without SDB suggest that factors in addition to those that influence directly pharyngeal CSA modify the predilection to SDB differentially across population subgroups.

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