Risk of Narrow Upper Airway in Class II Children with Large Horizontal Maxillary Overjet Assessed By Acoustic Reflection: a Case-Control Study

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ABSTRACT

Objectives: The aim of this case-control study was to examine upper airway by acoustic reflection in class II children with large horizontal maxillary overjet compared to children with neutral occlusion.
Material and Methods: The study group included children of 9 to 14 years with class II and large horizontal maxillary overjet (≥ 6 mm) compared to children with neutral occlusion (controls). Acoustic pharyngometry and rhinometry were performed in natural head position. Differences between groups were tested by chi-square test, general linear model (adjusted for age, gender and body mass index [BMI]), and Mann-Whitney test.
Results: The study and control group consisted of 37 (boys: 19, girls: 18) and 32 (boys: 16, girls: 16) participants, respectively. No significant differences in age, gender, and BMI were found between the groups. For the acoustic rhinometry measurements significantly increased resistance (P = 0.04), reduced volume (P = 0.03) and distance to minimal cross-section area (MCA) (P = 0.035) were found in the study group, but only for the right nostril. However, significantly reduced MCA for both nostrils was found in the study group (P = 0.025 to 0.04). No significant differences in acoustic pharyngometry measurements were found.
Conclusions: Nasal airway dimensions were significantly reduced, and nasal resistance was significantly increased in the study group compared to controls. Thus, class II and large overjet with indication for growth adaptive treatment may be a risk factor for sleep-disordered breathing. In the future, orthodontic paediatric patients may benefit from non-invasive risk assessment of narrow upper airway using acoustic reflection.

Keywords: acoustic rhinometry; acoustics; airway resistance; angle class II; child; malocclusion.

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INTRODUCTION

Sleep related disorders as for example sleep-disordered breathing (SDB) has a great impact on children's growth, development, and well-being. Accordingly, it is important to prevent and diagnose SDB in children and adolescents [1]. Predisposing factors for SDB are primarily adenotonsillar hypertrophy and/or adenoid vegetations [1,2]. As upper airway dimensions and dento-craniofacial development are closely related, obstruction of nasal airways may result in abnormal dento-craniofacial development and mouth breathing [1,2]. Likewise, dento-craniofacial morphology may have a great influence on the dimensions and the resistance of the upper airway. Additionally, studies have shown that different anatomical variations of the dento-craniofacial morphology may increase the risk of increased resistance and reduced volume of the upper airway. Example of these different dento-craniofacial traits may be convex facial profile, high and narrow palate, increased lower vertical face height, and mandibular retrognathia [3-6].

Angle class II malocclusion with large horizontal maxillary overjet (large overjet) due to mandibular retrognathia is one of the most common malocclusions in children and adolescents [7]. The majority of these children and adolescents have indication for growth adaptation of the mandible during their pubertal growth spurt with functional appliance [8-10]. Accordingly, examination of the upper airway in this group of children is of high relevance to assess the risk of SDB [3-5,8,11-13].

Previous studies have shown that acoustic pharyngometry and rhinometry are useful, non-invasive methods [14,15] that are reliable in children and adolescents and can be used in risk assessment of SDB [15,16]. As acoustic reflection is non-invasive, it is possible to examine the upper airway resistance and dimensions in children and adolescents without radiation exposure when lateral cephalograms or cone-beam computed tomography (CBCT) are not indicated [14].

No previous study has used acoustic reflection to examine if children with class II and large overjet with indication for growth adaptive treatment have increased resistance and reduced upper airway dimensions. Accordingly, acoustic reflection has not previously been used to describe an eventual clinical risk assessment of SDB in this pediatric, orthodontic population. The null hypothesis of the present case-control study was that there was no significant difference in upper airway dimensions and resistance, assessed by acoustic pharyngometry and rhinometry, between children with class II and large overjet compared to children with neutral occlusion.

MATERIAL AND METHODS

The present study was conducted at the Section of Orthodontics, Department of Odontology, University of Copenhagen, Denmark from August 26, 2020 to June 1, 2023. It was registered at ClinicalTrials.gov (registration no. NCT04964830) prior to the recruitment of participants. Some of the previously published papers were partly based on the same cohort but on different topics [16-19]. This study was approved by the Committee on Health Research Ethics for the Capital Region (protocol no. H-17011521) and the Danish Data Protection Agency (protocol no. SUND-2017-29). A written informed consent was obtained from the children's parents/caregivers prior to the enrolment. The study followed the declaration of Helsinki and was conducted according to the STROBE statements [20].

Study sample

The power calculation was based on previous studies [5,8], and it was assumed that children in the present study group have 40% risk of narrow upper airway dimensions and that children in the control group have a risk of 10%. With a risk of type 1 error of 5%, risk of type 2 error of 20%, and power of 80%, at least 32 participants should be included in both the study and control group to have sufficient power.

Subjects

The participants were included for a study group and a control group [16-19] from August 26, 2020 to June 1, 2023. The participants were recruited from different municipal dental health care centres in the area of Copenhagen, Denmark and the Postgraduate Program in Orthodontics, Department of Odontology, University of Copenhagen.

The study group consisted of children aged 9 to 14 years with class II and horizontal maxillary overjet ≥ 6 mm with indication for growth adaptive treatment of the mandible during the pubertal growth spurt [8-10]. The participants in the study group had moderate to severe mandibular retrognathia [10] (retrognathia of the mandible 75.6° [SD 3.5°] and ANB angle 5.1° [SD 1.5°]) assessed on lateral cephalograms in standard natural head position, using the mirror position [21]. The cephalometric X-rays were taken of the participants in the study group as part of the orthodontic treatment planning.

The control group included children aged 9 to 14 years with neutral occlusion [22] and with no indication for orthodontic treatment according to the procedure for screening the child population for severe malocclusion entailing health risks [23]. Exclusion criteria for both groups were syndromes, diseases, SDB, adenoid vegetations, and hypertrophied tonsils.

Methods

General recordings

Height in meters and weight in kilograms were obtained to calculate body mass index (BMI, kg/m^2). BMI was graded individually in the categories "underweight", "normal weight", and "overweight" according to their age in months and gender [24]. Horizontal maxillary overjet and vertical overbite were clinically registered [10,22].

Acoustic pharyngometry and rhinometry

The upper airway dimension and upper airway resistance of the participants were examined using the Eccovision® Acoustic Pharyngometer and Rhinometer (Sleep Group Solutions; Hollywood, Florida, USA). Acoustic pharyngometry and rhinometry were calibrated and performed according to the operator manual [25], and in standing natural head position, using the mirror position, as previously described in details [16,26]. All examinations were performed by the same examiner (C.H.). The following measurements were registered: volume, mean area of the pharynx, calculated resistance of the nostrils, minimum cross-sectional area (MCA), and distance to MCA. A recording was excluded if the graph continued through the upper border of the screen [16].

Reliability

For assessment of the reliability of the craniofacial morphology of the study group, 25 lateral cephalograms were randomly chosen to be scored again after two weeks. No systematic error was found. The method error ranged between 0.2° to 1.72° [27,28] and the reliability coefficient ranged between 0.896° to 0.995° [27,28]. Regarding the acoustic pharyngometry and rhinometry, the method error ranged between 0.001 to 0.082, and Houston reliability coefficient ranged between 0.956 to 0.999 as previously reported [16].

Statistical analysis

Statistical data analyses were performed using the SPSS® Statistics version 29.0 (IBM Corp.; Armonk, New York, USA). Descriptive statistics were made, and test of normality of the residuals for all variables were tested by Quantile-Quantile-plots. Differences in gender were tested by chi-square test, and differences in age and BMI across the groups were tested by non-parametric Mann-Whitney test. Differences in horizontal maxillary overjet and vertical overbite were analysed between the groups using general linear model (GLM) adjusted for age and gender.

Differences between the groups of the normally distributed data were analysed using GLM adjusted for age, gender, and BMI. Volume of the nostrils was transformed using the natural logarithm to be normally distributed and then the difference between the two groups were analysed by GLM adjusted for age, gender, and BMI. Afterwards the results were back-transformed using exponential function and the relative differences between the explanatory variables were listed. Distance to MCA of the nostrils were non-normally distributed and analysed by non-parametric Mann-Whitney test. A participant was excluded from analysis of a specific variable in the presence of missing data of the specific variable. Parametric data was expressed as mean and standard deviation (M [SD]) and 95% confidence intervals and non-parametric data as quartiles. The significance level was set at 5%.

RESULTS

The flowchart of participants is shown in Figure 1. In total, 62/69 (90%) of the acoustic pharyngometry recordings and 66/69 (96%) acoustic rhinometry recordings were sufficient for further analyses. General descriptive statistics regarding gender, age, BMI, and incisal relationship of the groups are shown in Table 1. No significant differences in age, gender, and BMI were found between the groups. The results of the pharyngometry and rhinometry are shown in Table 2 and 3, respectively, comparing the study group and the control group adjusted for gender, age, and body mass index categories.

Significantly larger calculated resistance ($P = 0.04$) and reduced volume of the right nostril ($P = 0.03$) were found in the study group compared to controls (Table 3). The distance to MCA of the right nostril was significantly larger in the study group ($P = 0.035$) compared to controls. Significantly reduced MCA for both nostrils ($P = 0.025$ to 0.04) were found in the study group compared to controls (Table 3).

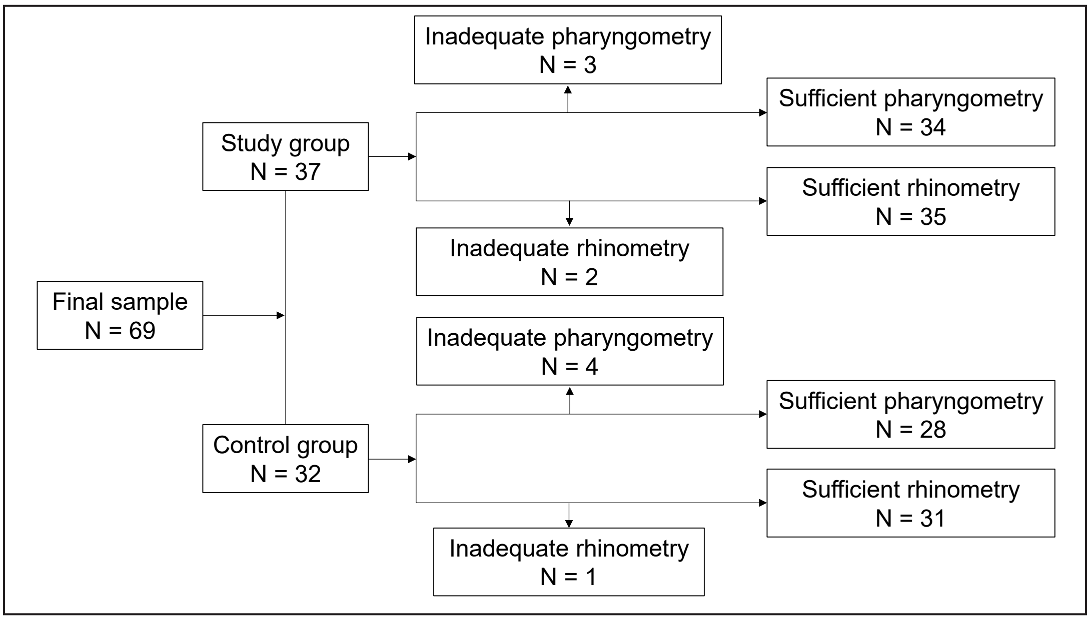

Figure 1. Flowchart of the acoustic pharyngometry and rhinometry examination of the participants in the study.

Table 1. Descriptive statistics of the groups

		Group		P-value
		Study	Control	
Participants	N	37	32	-
Gender	N (boys; girls)	19; 18	16; 16	0.911[a]
Age (years)	Median (min; max)	12.3 (9.8; 14.7)	12.2 (9.5; 14.6)	0.527[b]
Body mass index categories				
Underweight	N (%)	10 (27)	2 (6)	0.507[b]
Normal weight	N (%)	24 (65)	21 (66)	
Overweight	N (%)	3 (8)	9 (28)	
Horizontal maxillary overjet (mm)	Mean (95% CI)	9 (8.3; 9.7)	2.7 (2.4; 3)	< 0.001[c]*
Vertical overbite (mm)	Mean (95% CI)	4.1 (3.6; 4.6)	3 (2.7; 3.4)	< 0.001[c]*

[a]Chi-square test; [b]Mann-Whitney test; [c]general linear model adjusted for age and gender.
*Statistically significant difference at P < 0.001.
N = number; CI = confidence interval.

Table 2. Acoustic pharyngometry measurements

		Group		P-value	Difference of the mean	95% CI of the difference	
		Study	Control			Lower	Upper
Volume (cm^3)	Mean (SD)	25.14 (5.32)	24.27 (5.2)	0.628[a]	0.667	-2.073	3.407
	95% CI of mean	23.28; 27	22.24; 26.27				
	Min; max	17.09; 34.43	13.22; 34.19				
Mean area (cm^2)	Mean (SD)	2.51 (0.53)	2.41 (0.52)	0.565[a]	0.079	-0.195	0.353
	95% CI of mean	2.32; 2.7	2.21; 2.61				
	Min; max	0.71; 3.44	1.32; 2.1				
MCA (cm^2)	Mean (SD)	1.7 (0.45)	1.55 (0.34)	0.259	0.126	-0.095	0.347
	95% CI of mean	1.54; 1.88	1.42; 1.68				
	Min; max	0.98; 2.53	1; 2.17				
Distance to MCA (cm)	Mean (SD)	12.81 (3.26)	13.12 (3.51)	0.63[b]	-0.42	-2.159	1.319
	95% CI of mean	11.67; 13.95	11.75; 14.48				
	Min; max	10.16; 19.17	10.16; 18.74				

[a]Positively associated with increased age; [b]significantly increased in boys.
MCA = minimum cross-sectional area; SD = standard deviation; N = number; CI = confidence interval.

Table 3. Acoustic rhinometry measurements

		Group		P-value	Difference of the mean	95% CI of the difference	
		Study	Control			Lower	Upper
Left nostril							
Calculated resistance (cm H_2O/L/min)	Mean (SD)	2.54 (1.11)	2.35 (1.49)	0.602[c]	0.168	-0.473	0.809
	95% CI of mean	2.26; 2.93	1.8; 2.9				
	Min; max	1.11; 5.58	0.31; 7.69				
Volume (cm^3)[a]	Mean (SD)	6.64 (1.38)	7.06 (1.57)	0.951[d]	0.595	0.787	1.148
	95% CI of mean	5.94; 7.42	5.98; 8.34				
	Min; max	3.9; 12.81	2.86; 23.57				
MCA (cm^2)	Mean (SD)	0.53 (0.1)	0.63 (0.25)	0.025[d]*	-0.109	-0.204	-0.014
	95% CI of mean	0.49; 0.56	0.54; 0.73				
	Min; max	0.31; 0.75	0.38; 1.49				
Distance to MCA (cm)	Q1	0.42	0.18	0.158[b]	-	-	-
	Q2	0.42	0.42		-	-	-
	Q3	1.86	1.62		-	-	-
	Min; max	0.18; 2.1	0.8; 4.5		-	-	-
Right nostril							
Calculated resistance (cm H_2O/L/min)	Mean (SD)	2.78 (1.13)	2.17 (1.04)	0.04[c]*	0.58	0.027	1.134
	95% CI of mean	2.39; 3.16	1.79; 2.55				
	Min; max	0.85; 5.78	0.21; 4.84				
Volume (cm^3)[a]	Mean (SD)	6.17 (1.38	7.73 (1.62)	0.03[d]*	0.793	0.645	0.977
	95% CI of mean	5.52; 6.9	6.47; 9.24				
	Min; max	3.49; 15.49	4.18; 36.23				
MCA (cm^2)	Mean (SD)	0.52 (0.11)	0.62 (0.27)	0.04[d]*	-0.109	-0.212	-0.005
	95% CI of mean	0.48; 0.56	0.52;0.72				
	Min; max	0.35; 0.76	0.4; 1.55				
Distance to MCA (cm)	Q1	0.18	0.18	0.035[b]*	-	-	-
	Q2	1.62	0.42		-	-	-
	Q3	1.86	1.62		-	-	-
	Min; max	0.2; 2.1	0.2; 1.9		-	-	-

[a]The relative differences are listed due to analysis using the natural logarithm scale; [b]Mann-Whitney test; [c]significantly negatively associated with age; [d]significantly positively associated with age.
*Significant difference at $P < 0.05$.
MCA = minimum cross-sectional area; SD = standard deviation; CI = confidence interval; Q1 = first quartile; Q2 = second quartile, median; Q3 = third quartile.

The calculated resistance was negatively associated with age (P = 0.002 to 0.011). The volume (P = 0.001 to 0.014) and the MCA of the nostrils (P = 0.022) were positively associated with age. No significant differences between the groups were found for the left nostril regarding calculated resistance, volume, or distance to MCA. No significant difference in the pharyngometric measurements was found. Although, the volume (P = 0.033) and mean area (P = 0.032) were significantly positively associated with age, and the distance to MCA (P = 0.025) was significantly increased in boys.

DISCUSSION

The present study is the first to examine upper airway dimension in children with class II and large overjet with indication for growth adaptive treatment compared to a control group using acoustic pharyngometry and rhinometry. This type of malocclusion represents the majority of young patients with indication for orthodontic treatment in the juvenile and adolescent period. Accordingly, this population is highly clinical relevant to examine. The power calculation was fulfilled, the success rates of the acoustic pharyngometry (90%) and rhinometry (96%) were high [15]. The method error for both acoustic pharyngometry and rhinometry was considered good [16,26]. However, training of the method before final registration may be beneficial [16].

Overall, the study showed that class II and severe large overjet was associated with risk of narrow nasal upper airway dimensions. Significantly larger nasal resistance of the right nostril was found in the study group but no difference for the left nostril. This difference between the nostrils may be due to local, anatomical factors. Reduced volume and MCA for both nostrils and reduced distance to the MCA of the right nostril were found in the study group compared to controls. The results are in accordance with previous studies based on lateral cephalograms and CBCT [3,6,8,29,30]. The findings of narrow nasal upper airways in children with class II and large overjet by acoustic rhinometry is of great clinical relevance as acoustic reflection is a non-invasive method. Accordingly, it may be beneficial to use this method as a part of a clinical risk assessment of narrow upper airway. As narrow upper airway is associated with SDB [6,8], children with class II and large overjet and reduced nasal airway dimensions may have increased risk of SDB.

No significant differences in the results of the acoustic pharyngometry were found between the groups. The results are in contrast with previous studies based on lateral cephalograms and CBCT [6,30,31], which found reduced pharyngeal volume and MCA in children with increased sagittal jaw relation. Previous studies found that acoustic reflection differ from measurements on CBCT, computed tomography and magnetic resonance [32-35], while other studies found moderate to good correlation with CBCT and lateral cephalogram [30,32]. The discrepancy in the literature may be due to the individual variation and morphology of the upper airway, which are influenced by multiple factors [1,2], e.g. age, gender, BMI, dento-craniofacial morphology, and head posture [1,3,4,11,36-40]. Accordingly, it is a strength that all examinations are performed in standing natural head position, using the mirror position [16,21,26,36-39]. Furthermore, the acoustic reflection and CBCT take the transverse dimension into account in contrast to the lateral cephalograms [33]. A limitation in the present study may be the compensatory mechanism due to extended head posture of the participants in the study group [21], which may have camouflaged an eventual difference in the pharyngeal airway volume [36,41]. In addition, it may be a limitation that no X-rays for analysis of the craniofacial morphology of the control group was taken due to ethical reasons. Consequently, the degree of dentoalveolar compensation mechanism in the control group may have camouflaged a skeletal discrepancy of the jaws. Therefore, this limitation was attempted to be minimized as the participants in the control group had neutral occlusion with no indication for orthodontic treatment [42].

The volume and mean area of the pharynx and the volume and MCA of the nasal airway were positively associated with age, whereas the calculated resistance of the nostrils was negatively associated with age. These results are in accordance with the increase of the volume of the upper airway during growth, including increased age and skeletal maturation [6,43]. Accordingly, children with narrow nasal upper airway may benefit from transverse expansion of the maxilla and growth adaptation treatment of the mandible during their pubertal growth spurt [6,8,44-47]. No significant association between the results of the acoustic pharyngometry and rhinometry and gender were found, besides the distance to MCA, which was increased in boys. This is in accordance with previous studies on children and adolescents [6,48,49] but in contrast to results of an adult population assessed by computed tomography [43].

In this study, no significant effect of BMI on the upper airway was found, which is surprising as previous studies have shown that increased BMI may be associated with reduced dimensions and increased resistance of the upper airway [2,15,40,50]. The reason for this result may be due to variation in underweight and overweight between the groups and the dento-craniofacial morphological deviations in the study group.

The present study improves the understanding of acoustic assessment of the upper airway in children with class II and large overjet with indication for growth adaptive treatment of the mandible. Because narrow upper airway is of great importance for the risk of SDB [1,4] whose etiology is multifactorial [1,2], studies using non-invasive techniques to examine or screen for narrow upper airway may prove valuable. Future research may examine the effect of growth adaptive treatment of the mandible with removable functional appliance on upper airway dimensions and resistance compared to a control group. However, inclusion and exclusion criteria for such studies should be clear and consistent. Furthermore, statistical adjustment of possible confounding factors should be performed, as airway resistance can be affected by multiple factors [1,2]. The results of the present study may contribute to an increased focus on the importance of interdisciplinary collaboration between medical doctors and specialists in orthodontics in diagnostics, prevention, and treatment of non-syndromic children at risk for narrow upper airways.

CONCLUSIONS

The study was the first of its kind to demonstrate reduced nasal airway dimensions in children with class II and large overjet with indication for growth adaptive treatment of the mandible compared to children with neutral occlusion using acoustic reflection. Bias regarding age, gender and body mass index were minimized in the study due to a comparable control group and statistical adjustments. The study showed that class II and severe large overjet is associated with risk of narrow upper airway dimensions. The results may prove valuable in using acoustic rhinometry as a non-invasive risk assessment of narrow upper airways in children with class II and large overjet to prevent and diagnose eventual risk of sleep-disordered breathing.

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