Reliability of Acoustic Pharyngometry and Rhinometry Examination in Children and Adolescents

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ABSTRACT

Objectives: The aim of this cross-sectional study was to examine the method error and reliability of acoustic pharyngometry and rhinometry in children and adolescents and to describe the feasibility of these methods in a young population.
Material and Methods: The study sample included 35 healthy subjects in the age of 9 to 14 years. The subjects were randomly recruited for the present project in the period from June 2021 to February 2022. Repeated measurements of the upper airway dimensions in standing mirror position were performed by the use of Acoustic Pharyngometer and Rhinometer. Volume (cm^3), calculated resistance (cm H_2O/L/min), mean area (cm^2), minimum cross-sectional area (MCA, cm^2) and distance to MCA (cm) were examined. Method errors and reliability coefficients were evaluated using Dahlberg's formula and the Houston reliability coefficient. The feasibility of the methods were analysed using paired t-test and estimated by difference in drop-out rates.
Results: No systematic error exhibited in the repeated measurements except volume in the left nostril ($P = 0.017$). The method errors of the acoustic pharyngometry and rhinometry were betweeen 0.0002 to 0.069 and 0.001 to 0.082 respectively. The Houston reliability coefficient for both methods were between 0.952 to 0.999. The acoustic pharyngometry was significantly more feasible compared to rhinometry ($P < 0.001$).
Conclusions: The study shows that acoustic pharyngometry and rhinometry in the standing mirror position are reliable methods, with acoustic pharyngometry being even more feasible than rhinometry, which is why it is recommended to practice the methods with children and ensure reliability of results before registering measurements.

Keywords: acoustics; child; pharynx; nose; reproducibility of results.

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INTRODUCTION

Acoustic pharyngometry and rhinometry are useful, non-invasive techniques to determine the dimensions and volumes of the upper airway [1-4]. Previous studies have demonstrated that these techniques are beneficial in clinical diagnostics and treatment planning, and evaluation of adults with obstructive sleep apnea (OSA) treated with a mandibular advancement device [5,6].

The dimension of the upper airway varies according to body position [7,8], which is why it is important to use the same body position, including head posture, each time a measurement is recorded. Several studies have documented that a natural head posture is a feasible and reproducible position when determining upper airway dimensions on lateral cephalograms and cone-beam computed tomography (CBCT) [9-12].

In addition, some previous studies [13-15] have found moderate to good validity when comparing acoustic reflection to CBCT, computed tomography (CT) and magnetic resonance (MRI), while others found the validity more doubtful compared to CBCT and CT [14,16,17]. Nevertheless, acoustic reflection is a non-invasive technique without any radiation exposure [1,2].

Knappe and Sonnesen [12] showed that acoustic pharyngometry and rhinometry are reliable methods, especially in standing mirror position in adults. Only a few studies have examined upper airway dimensions in children and adolescents using acoustic pharyngometry and rhinometry [8,18].

To date, there are few studies that have examined the validity, repeatability and short term intersession reproducibility of the acoustic pharyngometry and rhinometry methods in children and adults [18-20]. To the authors' knowledge, only one previous study has examined the reliability of acoustic pharyngometry in children and adolescents [18].

However, no study has so far examined the reliability and feasibility of acoustic pharyngometry and rhinomety in children and adolescents using standing mirror position.

It is hypothesised that the reliability for repeated measurements in acoustic pharyngometry and rhinometry performed in standing mirror position on children are sufficient and feasible to perform. The aim of this cross-sectional study is thus to examine the method errors as well as the reliability and feasiblity of acoustic pharyngometry and rhinometry in standing mirror position in children and adolescents.

MATERIAL AND METHODS

Subjects

The sample in the present study consisted of 35 children and adolescents (19 boys and 16 girls) at the age of 9 to 14 years (mean 13.09, median 13.08, 95% CI [confidence interval] = 12.66 to 13.51) out of 39 children and adolescents randomly enrolled for the study in the period from 1 June 2021 to 25 February 2022 (Figure 1).

The subjects were enrolled for another study conducted at the Section of Orthodontics, Department of Odontology, University of Copenhagen, which was approved by the Committee of Research Health Ethics of the Capital Region (Protocol no. H-17011521) and the Danish Data Protection Agency (Protocol no. SUND-20017-29) and registered at clinicaltrials.gov (reg. no. NCT04964830).

The inclusion criteria were: age 9 to 14 years, no general syndromes or diseases, no chronic respiratory diseases or asthma, no adenoid vegetations, hypertrophic tonsils or mouth breathing, and informed consent from parent(s)/guardian(s).

When a power analysis was performed under the assumption that differences were found in 50 percent of the repeated measurements, at least 17 participants were required in order to have sufficient power (80%) to identify statistically significant differences at the 5% level of significance. Thus, the 35 participants included in the present study were considered sufficient.

Methods

The subjects had standing acoustic pharyngometry and rhinometry performed by the same examiner (C.H.) at the Section of Orthodontics, Department of Odontology, University of Copenhagen. The examiner was trained according to the Eccovision® Acoustic Pharyngometer and Rhinometer (Sleep Group Solutions; Hollywood, Florida, USA) operator manuals [21] and the examinations were performed in standing mirror position as described in Knappe and Sonnesen [12]. All subjects had both acoustic pharyngometry and rhinometry performed once and subsequently repeated after a minimum of 15 minutes. If a registration was of insufficient quality the registration was performed again after reinstruction, and the participant had at least three attempts before a registration was registered as 'not correctly interpreted'.

The system was calibrated according to the operator manual before the acoustic rhinometry took place [21]. The Eccovision® Acoustic Pharyngometer

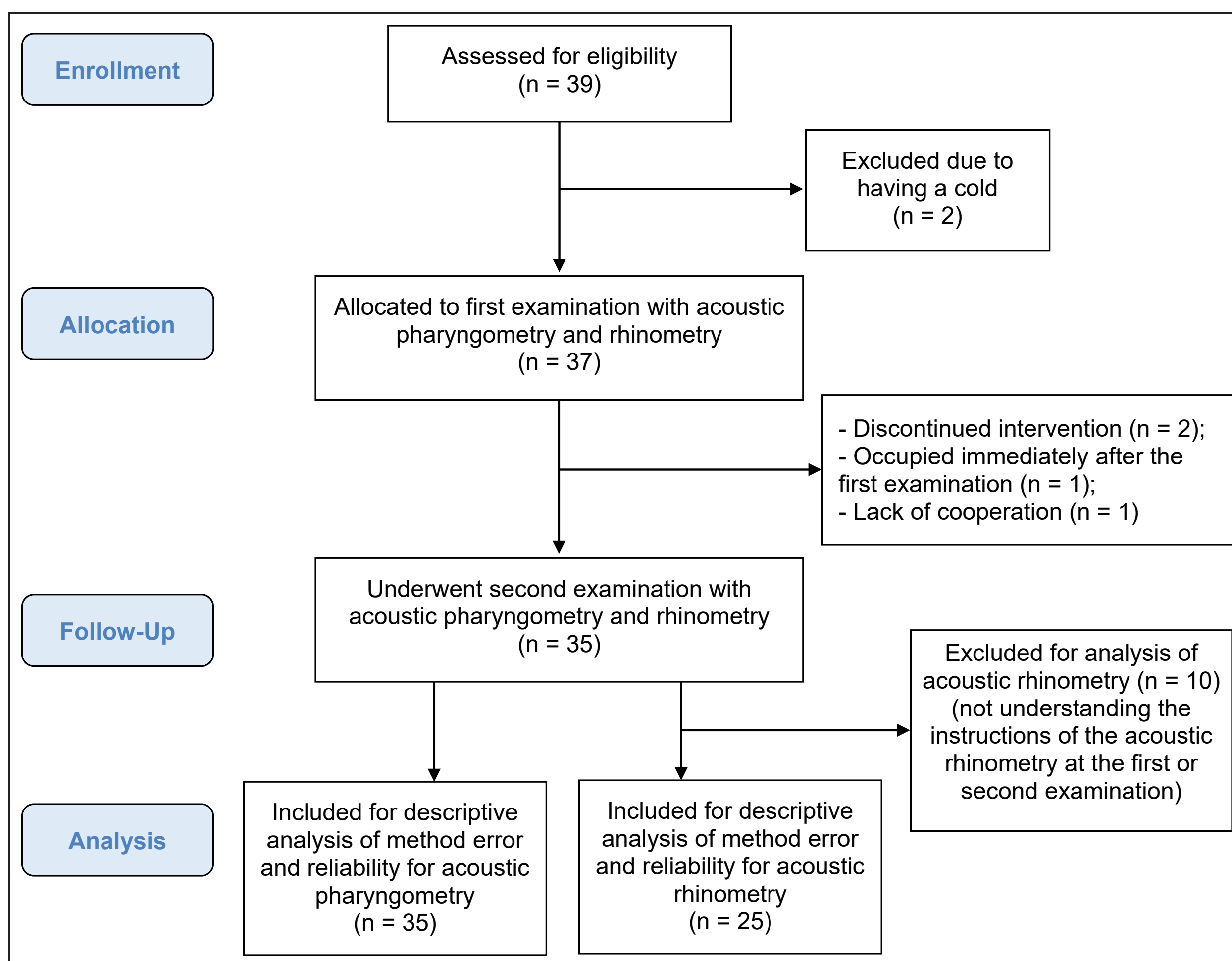

Figure 1. The CONSORT Flow diagram of the cross-sectional study.

and Rhinometer (Sleep Group Solutions; Hollywood, Florida, USA) programme showed measurements in the following areas for acoustic pharyngometry: volume (cm^3), mean area (cm^2), minimum cross-sectional area (MCA, cm^2) and distance to MCA (cm). For acoustic rhinometry: calculated resistance (cm H_2O/L/min), volume (cm^3), MCA (cm^2) and distance to MCA (cm) (Figure 2 and 3).
The feasibility of each of the two methods was registered by a visual assessement of the graph on the screen of the Eccovision® whilst performing the acoustic pharyngometry and rhinometry. If the graph continued through the upper border of the screen instead of the right border of the screen, the subjects' performances were registered as "not correctly interpreted" (Figure 4) [21].

Statistical analysis

The statistical analyses are performed in IBM SPSS Statistics version 27.0 (IBM Corp.; Armonk, New York, USA). The systematic error between the repeated measurements of the acoustic pharyngometry and rhinometry was analysed using a paired t-test. Significant level was set at P = 0.05. The method errors of the repeated measurements of acoustic pharyngometry and rhinometry were calculated using Dahlberg's formula and the Houston reliability coefficient, respectively [22,23]. The feasibility between the two methods was recorded by the drop-out rate, which was analysed by paired t-test. Parametric data were expressed as mean and standard deviation (M [SD]).

RESULTS

The descriptive statistics mean (SD), mean differences (SD), confidence intervals of the differences, systematic error, method error, and reliability coefficient results are listed in Table 1. No systematic error between the repeated measurements of acoustic pharyngometry and rhinometry was found except for volume in the left nostril (P = 0.017). Method errors for acoustic pharyngometry in standing position in children and adolescents were 0.069 for the volume (cm^3), 0.008 for the mean area (cm^2),

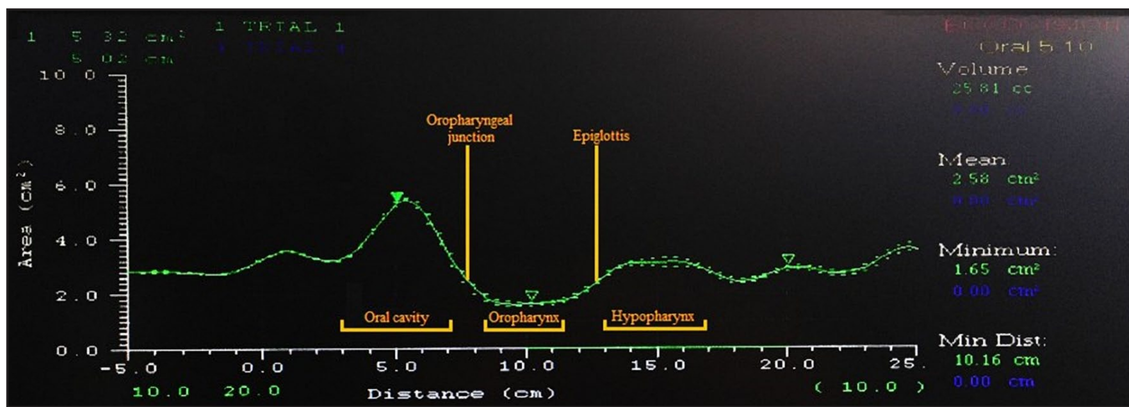

Figure 2. Graphical and numerical measurements of the dimensions of the pharyngeal airway performed by acoustic pharyngometry.

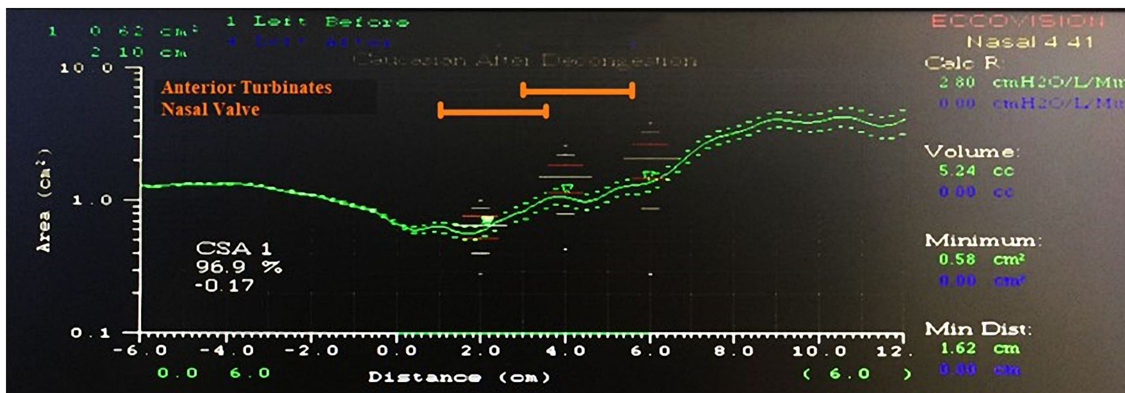

Figure 3. Graphical and numerical measurements of the dimensions of the nasal airway performed by acoustic rhinometry.

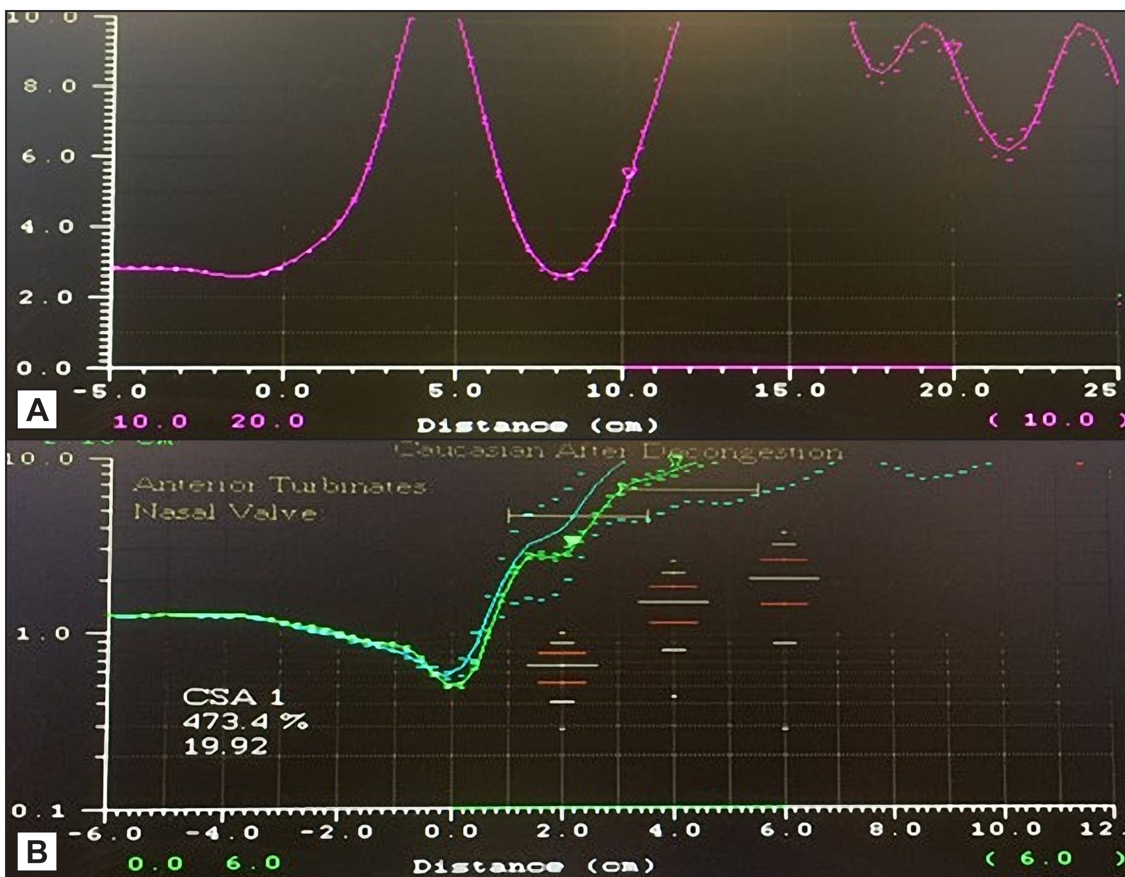

Figure 4. Graphical illustration of measurements of acoustic pharyngometry (A) and rhinometry (B) categorised as 'not correctly interpreted'.

Table 1. Mean values, mean difference, standard deviation, 95% confidence interval (CI), method error and reliability coefficient of the whole sample's difference between the first and second measurements when performing repeated measurements of acoustic pharyngometry and rhinometry in standing mirror position

	First	Second	Mean difference (SD)	95% CI	Method error (s(i))	Reliability (Houston)
	Mean (SD)	Mean (SD)				
Acoustic pharyngometry						
Volume (cm^3)	24.25 (5.18)	24.83 (5.25)	-0.578 (2.486)	-1.401; 0.246	0.069	0.986
Mean area (cm^2)	2.42 (0.52)	2.49 (0.53)	-0.063 (0.253)	-0.147; 0.021	0.008	0.985
Minimum cross-sectional area (MCA, cm^2)	1.66 (0.31)	1.66 (0.26)	-0.001 (0.214)	-0.072; 0.069	0.0002	0.999
Distance to MCA (cm)	13.96 (3.87)	13.58 (3.51)	-0.38 (1.355)	-0.829; 0.069	0.045	0.987
Acoustic rhinometry, left nostril						
Calculated resistance (cm H_2O/L/min)	2.36 (0.98)	2.44 (0.84)	-0.083 (0.612)	-0.323; 0.157	0.012	0.986
Volume (cm^3)	7.23 (2.22)	6.66 (1.7)	0.577 (1.278)	0.076; 1.078	0.082	0.956
Minimum cross-sectional area (MCA, cm^2)	0.55 (0.1)	0.54 (0.08)	0.010 (0.088)	-0.024; 0.045	0.001	0.982
Distance to MCA (cm)	1 (0.79)	1.18 (0.8)	-0.173 (0.695)	-0.445; 0.099	0.024	0.966
Acoustic rhinometry, right nostril						
Calculated resistance (cm H_2O/L/min)	2.27 (1.03)	2.35 (0.83)	-0.072 (0.795)	-0.384; 0.239	0.01	0.988
Volume (cm^3)	7.11 (1.87)	6.98 (1.87)	0.126 (1.933)	-0.632; 0.884	0.018	0.989
Minimum cross-sectional area (MCA, cm^2)	0.58 (0.14)	0.55 (0.09)	0.032 (0.146)	-0.026; 0.089	0.004	0.952
Distance to MCA (cm)	0.89 (0.74)	0.85 (0.78)	0.043 (0.662)	-0.216; 0.303	0.006	0.991

MCA = minimum cross-sectional area; SD = standard deviation.

0.0002 for the MCA (cm^2) and 0.045 for the distance to MCA (cm). The reliability coefficients for the acoustic pharyngometry ranged from 0.985 to 0.999.

Method errors for acoustic rhinometry in standing position in children and adolescents ranged from 0.010 to 0.012 for the calculated resistance (cm H_2O/L/min), from 0.018 to 0.082 for the volume (cm^3), from 0.001 to 0.004 for the MCA (cm^2) and from 0.006 to 0.024 for the distance to MCA (cm). The reliability coefficients for the acoustic rhinometry ranged from 0.952 to 0.991. The feasibility was reduced for the acoustic rhinometry compared to the acoustic pharyngometry due to significantly higher drop-out rate in the acoustic rhinometry ($P < 0.001$).

DISCUSSION

The mean values in the present study are reduced compared to studies made on adults [12,20], which was expected, due to skeletal maturation during the adolescent growth period and upper airway dimensions being positively associated with age and skeletal maturation [18,24]. Accordingly, the results of the acoustic rhinometry were comparable to previous reference values in younger children aged 4 to 13 years old [19]. On the other hand, the results of the acoustic pharyngometry cannot be compared to similar paediatric studies.

In general, the present study demonstrated that acoustic pharyngometry and rhinometry are reliable methods to use for determining upper airway dimensions in children and adolescents.

In the present study, the method errors were below 0.09, which is considered good, and the reliability of the repeated measurements were very good. The results af the present study were in accordance with previous studies on adults focussing on repeated measurments performed using similar methods [2,4,12,20]. The present study found higher reliability of repeated measurements in constrast to previous studies regarding acoustic pharyngometry [4,18], but Monahan et al. [18] examined children in the age of 8 to 11 years using only acoustic pharyngometry and not rhinometry. Yet, when the results of the present study are compared to similar studies on adults, the reliability is not as high for children as for adult patients, which may be due to a higher degree of inability to follow instructions [12]. Accordingly, a limitation of the present study is that only two registrations of sufficent quality with at least 15 minutes interval were made, in constrast to Monahan et al. [18], which made at least three registrations of sufficient quality of each subject.

In the present study, no systematic error was found except for the volume of the left nostril ($P = 0.017$). Ahmari et al. [25] showed high repeatability of the rhinometry in adults and calculated the mean of several registrations over five days, which points to

a limitation of the present study that only included two registrations at the same day.

The majority of previous studies were usually performed using sitting and supine position [8,18,20,25]. As the dimensions of the upper airway varies according to body position and head posture [7,8], a highly reproduceable position as natural head posture is required [9-12]. Accordingly, Knappe and Sonnesen [12] found significant better reliability using standing mirror position compared to sitting position. In addition, other studies have shown that the standing mirror position is a well-validated method [9-11, 26-29].

In general, the instructions for acoustic pharyngometry were easier for children to follow than for acoustic rhinometry, which was demonstrated in the present study through a significantly higher drop-out rate of the acoustic rhinometry compared to pharyngometry. Similarly, Bokov et al. [8] found a good success rate for acoustic pharyngometry and a higher dropout rate for acoustic rhinometry, as in the present study, although the registration methods regarding position differed between the studies. Moreover, the findings of a lower success rate for acoustic rhinometry, as compared to pharyngometry, is supported by Bokov et al. [8]. The instructions in "pausing" respiration were particularly difficult for children to understand, i.e. it was more difficult for subjects to simultaneously pause their breathing and stay in the standing mirror position during acoustic rhinometry than to follow the less complex step by step instructions for acoustic pharyngometry [30-33]. Some children lost focus faster than others, and instructions were generally harder for children to interpret and follow when they were already unfocused [30-33].

Previous studies have tested the validity of the acoustic pharyngometry and rhinometry methods compared to CBCT and MRI with moderate to good results [13-15] while other studies have shown more doubtful results [14,16,17]. The present study demonstrates that acoustic pharyngometry and rhinometry are reliable methods for determining upper airway dimensions in children and adolescents.

Furthermore, the methods are non-invasive and do not expose subjects to radiation [2]. Accordingly, acoustic pharygometry and rhinometry are useful methods for comparing upper airway dimensions in clinical longitudinal and case-control studies. For this reason, acoustic pharyngometry and rhinometry are useful supplementary examination methods for clinical extra- and intraoral examinations of children's and adolescents' upper airway dimensions and treatment effects [8,18].

The subjects were part of a different longitudinal study employing these methods. As such, a limitation of the present study is that some of the subjects had already previously attempted to perform acoustic pharyngometry and rhinometry, which may have made the procedure easier for them to perform. Consequently, mean calculations of several registrations of the first and the second measurements may have strengthened the reproduceabilty of the methods examined in the present study.

CONCLUSIONS

Acoustic pharyngometry and rhinometry are reliable methods to use for children and adolescents. However, the feasibility of acoustic rhinometry was reduced compared to acoustic pharyngometry. In particular, children may have difficulties following the instructions for acoustic rhinometry. It is recommended to repeat the methods with the subjects if it is unclear whether the instructions are difficult for the children to understand before registering measurements.

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