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Reference values for acoustic rhinometry in children at baseline and after decongestion*

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SUMMARY

Background: *Acoustic rhinometry is widely used for objective evaluation of nasal dimensions. However, there is a lack of agreement on the normative values in children at baseline, and especially after decongestion. The purpose of this study was to determine the reference values for Finnish school children for acoustic rhinometry in non-decongested and decongested noses, and to find out which of the potential predictors (age, sex, body surface area (BSA) and height) would be the most useful one(s).*

Methodology: *The study included 124 children aged between 6.90 and 13.84 years with no permanent nasal symptoms.*

Results: *At baseline, the mean total minimal cross-sectional area (MCA) was 0.752 cm², and the mean total volume between 0 - 3 cm (VOL) was 4.00 cm³. After decongestion, the total MCA was 0.794 cm², and the VOL was 4.38 cm³. There was a significant correlation between MCA and age, between VOL and height, and between VOL and BSA at baseline and after decongestion. We found no difference in the values between boys and girls.*

Conclusions: *We conclude that acoustic rhinometry is a suitable objective method to monitor the changes in mucosal swelling and nasal obstruction in children. Age and height or BSA of a child can be suggested as predictive factors.*

Key words: acoustic rhinometry, child, reference material, cross-sectional area, decongestion.

INTRODUCTION

Acoustic rhinometry is used for the evaluation of the nasal dimension [(1)]. The technique is based on the analysis of sound reflection from the nasal cavity. The curve calculated from the reflections describes the cross-sectional area as a function of distance. Acoustic rhinometry has been under development and is widely accepted as a reliable objective tool for nasal evaluation [(1-3)]. The Committee on Standardisation of Acoustic Rhinometry has presented guidelines for optimal application of the method [(4)].

Many reference values for the adult population have been established in the literature [(3,5,6)]. Efforts have also been made to find normal values for children in different age groups, and many studies give reference values for pre-school children [(7-9)].

In the study of Japanese school children between 7 and 8 years of age, Miyamoto et al., found the mean unilateral minimal cross-sectional area (MCA) to be 0.389 cm² [(10)]. In the study of Larsson et al., the normal values for school children aged 7 to 16 years (median age 11.1 years) were quite high (mean unilateral MCA 0.52 cm² ± 0.14) [(11)]. Similarly, in the group of children aged 6 and 7 years, Jurlina et al. found the total MCA in the isthmus area to be 1.01 cm² (SD 0.09) [(5)].

Almost all the reference values for MCA or nasal volume for children mentioned above have been measured in non-decongested noses. Recently, some values for children after decongestion have been published [(8,12-14)]. It is important to measure both values (before and after decongestion) to elicit the role of mucosal swelling.

Most publications present the values of acoustic rhinometry for a particular age group of children. Increasingly there has been debate about other factors influencing normal values. Samolinski et al. found that girls had slightly larger nasal cavities than boys up to the age of 11 years, but *vice versa* after the age of 11 years. The difference between boys and girls was significant when considering the cross-sectional area at the I-notch (isthmus area) [(15)]. Jurlina et al., have found a significant correlation between the body surface area (BSA) and MCA in healthy subjects over 6 years of age. In addition, they found a correlation between height and MCA and height and volume from 22 to 54 mm from the nosepiece [(5)]. In a large

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group of children (age 4 to 13 years), Straszek et al. found height to be a significant predictor for all acoustic variables measured, but neither age nor BSA was significantly associated with any of the variables [13].

One aim of the study was to define normative values for Finnish school children for acoustic rhinometry in non-decongested and decongested nose. The other aim was to find out which of the most potential predictors (age, sex, height and BSA) would be the most useful one(s).

MATERIALS AND METHODS

Study group

The study included 124 children aged between 6.90 and 13.84 years (mean 10.38 years). There were 59 boys (47.6%) and 65 girls (52.4 %) in the study group. The criteria for exclusion were any permanent nasal symptoms or acute upper respiratory infection within two weeks. Anterior rhinoscopy was performed to rule out prominent septal deviations and remarkable mucosal swelling.

Acoustic rhinometry

Acoustic rhinometry was performed on each subject (Acoustic Rhinometer A1, GM Instruments Ltd., Kilwinning, Scotland) according to the recommendations of the Committee on Standardisation of Acoustic Rhinometry [4]. The equipment was checked with an artificial nose delivered by the manufacturer every day before the first measurement (Figure 1).

Three measurements were performed on each side. The mean values of the three acceptable curves were used for calculations. Curves with significant deviation were excluded and the measurement was repeated if necessary. Medium-size anatomical nose adaptors were used. If necessary, ultrasound gel was used to prevent acoustic leakage. The children were asked to hold their breath, or allowed to breath quietly through the mouth.

The first measurement (baseline) was done after acclimatisation to the room temperature. After baseline measurements, the nose was decongested with two puffs of xylometazoline spray (Nasolin 0.5 mg/ml, Orion Oyj, Espoo, Finland) in each nostril. The measurements were repeated 10 minutes after decongestion. Children were asked to blow their nose before any measurements.

The acoustic values of special interest were the total minimal cross-sectional area (MCA) calculated as a sum of left and right sides, the mean distance of the minimal cross-sectional area from the nostril (DMCA), and the total nasal cavity volume 0 - 3 cm from the nostril (VOL) calculated as a sum of left and right sides. Total values were used to avoid the effect of nasal cycle. The same values were defined after decongestion of the nose.

The body surface areas (BSA) were determined using the data on height and weight of each child. All the measurements were done between November 2009 and January 2010 by the same author (LH) in two primary schools in South-Western Finland.

Written informed consent was elicited from every child and from his/her parents. The Joint Ethical Committees of Turku University and Turku University Hospital approved the study.

Statistics

The variables MCA and VOL were normally distributed according to the Shapiro-Wilk test. Pearson correlation coefficients were used to calculate the correlations between the acoustic values, MCA and VOL, and age, height and BSA as constant predictors.

On the other hand, the distribution of DMCA was not normally distributed, and Spearman correlation coefficients were used for calculations of correlations. To test the difference in acoustic values between boys and girls a two-sample t-test was used for MCA and VOL, and the Mann-Whitney U-test for DMCA. In the comparison of values between baseline and after decongestion a paired t-test and Wilcoxon Signed Rank test were used.

For further evaluation of the role of height in the acoustic values, four subgroups according to height were formulated (111 - 130 cm, 131 - 140 cm, 141 - 150 cm and 151 - 170 cm). The differences between subgroups were tested with one-way ANOVA using Tukey's post-hoc comparisons. DMCA values were compared with Kruskal-Wallis test.

The software used was SAS 9.2 for Windows. Values of $p < 0.05$ were considered statistically significant.

RESULTS

The mean age of the study group was 10.38 years (range 6.90 - 13.84 years, SD 1.68). The height of the children ranged from 117 cm to 170 cm (mean 142.4 cm, SD 11.4). The mean BSA was 1.22 m^2 (range 0.86 - 1.80 m^2, SD 1.20). The number of children at baseline and after decongestion is summarized in Table 1. For further calculations, children were divided into subgroups according to height (111 - 130 cm, 131 - 140 cm, 141 - 150 cm and 151 - 170 cm).

Acoustic values

At baseline, the mean total MCA was 0.752 cm^2 (SD 0.165), the mean DMCA was 1.168 cm (SD 0.399), and the total volume between 0 - 3 cm from the nostril cm was 4.00 cm^3 (SD 0.63). After decongestion, the total MCA was 0.794 cm^2 (SD 0.162), the mean DMCA was 1.066 cm (SD 0.278), and the total volume between 0 - 3 cm from the nostril was 4.38 cm^3 (SD 0.75).

The change in acoustic values between baseline and decongested nose was significant. The mean change in the MCA was 0.04 cm^2 ($p < 0.01$), in the DMCA -0.12 cm ($p < 0.01$), and in the VOL 0.41 cm^3 ($p < 0.001$).

There was no statistical difference in the acoustic values between boys and girls at baseline or after decongestion. At baseline, the mean total MCA was 0.75 cm^2 (SD 0.16), the mean DMCA was 1.21 cm (SD 0.42), and the total volume was 4.00 cm^3 (SD 0.63) in boys, and the mean total MCA was 0.75

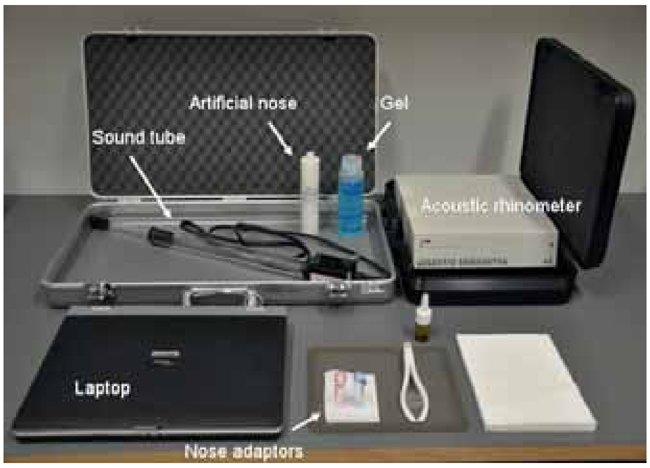

Figure 1. The ambulatory unit used for measurements.

cm^2 (SD 0.17), the mean DMCA was 1.13 cm (SD 0.38), and the total volume was 4.00 cm^3 (SD 0.64) in girls. After decongestion, the values were 0.79 cm^2 (SD 0.13), 1.13 cm (SD 0.33) and 4.28 cm^3 (SD 0.61) in boys, and 0.80 cm^2 (SD 0.19), 1.01 cm (SD 0.20) and 4.48 cm^3 (SD 0.85) in girls, respectively.

The mean MCA, DMCA and VOL 0-3 before and after the decongestion in the different subgroups of height are presented in Table 2. There was no statistical difference between the different subgroups in the MCA and DMCA values. VOL was higher in the subgroup 141 - 150 cm compared to subgroup 111 - 130 cm (p = 0.05) at baseline. After decongestion VOL was higher in the subgroup 131 - 140 cm compared to subgroup 111 – 130 cm (p = 0.05).

Correlations

There was a significant correlation between MCA and age at baseline and after decongestion. In addition, MCA correlated with height and BSA at baseline, but not in the decongested nose. Furthermore, there were no correlations between age and DMCA or VOL at any point. Instead, a significant correlation was found between VOL and height and VOL and BSA at baseline and after decongestion. The only correlation between DMCA and any predictive factor was found with BSA after decongestion. The correlation coefficients can be seen in Table 3.

DISCUSSION

Acoustic rhinometry is a commonly used method to evaluate nasal obstruction. The method is especially suitable for children because it is rapid, reliable and non-invasive with no side effects, and minimal co-operation is required [4,7,16,17]. However, the diversity of the acoustic values published for children so far has been slightly confusing.

In this study of children aged 7 - 14 years, the mean total MCA was 0.752 cm^2 (SD 0.165) and the total volume between 0 - 3 cm was 4.00 cm^3 (SD 0.63) at baseline. Local decongestion (xylometazoline spray) was used to elicit the role of mucosal swelling, and the values after decongestion were 0.794 cm^2 (SD 0.162) and 4.38 cm^3 (SD 0.75), respectively. Our values are in agreement with a recent study of school children aged 9 - 11 years [14].

Only a few studies, presenting both baseline values and values after decongestion for children have been published [12,14]. In our material, the change in the acoustic values after decongestion was significant, indicating that the values are reliable and the change in mucosal swelling is detectable with acoustic rhinometry. In addition, this finding is remarkable because the children in this study had no permanent nasal symptoms (e.g. chronic nasal obstruction) or previous acute upper respiratory infection within two weeks.

There was an increase in the mean total MCA and VOL and a decrease in the mean DMCA after the decongestion. This anterior movement of MCA was detected by Straszek et al., in the same way, and they found a significant increase in the MCA and VOL as well [14].

In recent years, there has been debate about factors influencing the values of acoustic rhinometry in children. Efforts have been made to establish normative values for nasal airway dimensions in relation to age and body size for optimal clinical use of the method [5,8,13,14,17,18]. On the other hand, some groups suggest that normal values are not useful in a single patient because of large inter-individual variations [6,11].

We found a correlation between total MCA and age at baseline and after decongestion of the nose. Age has been presented as a predictive factor also by other groups [15,17]. In the same way, we found a correlation between total anterior volume and height and BSA. Such weak correlations with height or BSA have also been found by other groups [5,13,18]. Moreover, Miyamoto et al. found a weak correlation between MCA and

Table 1. The number of children and the values of age, height and body surface area (BSA) at baseline and after decongestion.

Variable	Age (years)			Height (cm)			BSA (cm2)		
	N	Mean (Range)	SD	N	Mean (Range)	SD	N	Mean (Range)	SD
Baseline	122	10.33 (6.90-13.84)	1.68	118	142.4 (117-170)	11.42	111	1.22 (0.86-1.79)	0.20
After Decongestion	106	10.44 (6.90-13.84)	1.68	103	143.2 (117-170)	11.96	96	1.23 (0.86-1.79)	0.21

Table 2. The acoustic values in the different subgroups of height.

	Variable	MCA (cm^2)			DMCA (cm)			VOL (cm^3)		
		N	Mean	SD	N	Mean	SD	N	Mean	SD
Subgroup										
111-130 cm	**Baseline**	21	0.72	0.15	21	1.31	0.47	22	3.67	0.50
	After Decongestion	19	0.75	0.14	19	1.13	0.31	20	3.96	0.59
131-140 cm	**Baseline**	25	0.70	0.17	25	1.13	0.36	25	4.04	0.65
	After Decongestion	20	0.78	0.21	20	1.06	0.20	19	4.60	1.07
141-150 cm	**Baseline**	46	0.76	0.16	45	1.08	0.32	45	4.16	0.62
	After Decongestion	38	0.80	0.15	38	1.07	0.30	37	4.38	0.57
151-170 cm	**Baseline**	23	0.80	0.18	23	1.28	0.49	23	3.92	0.70
	After Decongestion	25	0.83	0.16	25	1.02	0.29	25	4.51	0.72
All	**Baseline**	119	0.75	0.17	118	1.17	0.40	119	4.00	0.63
	After Decongestion	105	0.79	0.16	105	1.07	0.28	104	4.38	0.75

MCA = minimal cross-sectional area (sum of left and right sides);
DMCA = distance of the minimal cross-sectional area from the nostril; VOL = volume between 0 - 3 cm from the nostril (sum of left and right sides).

Table 3. The correlations between acoustic values (MCA, DMCA and VOL) and age, height and BSA.

	Acoustic value	MCA		DMCA		VOL	
		Baseline	After Decongestion	Baseline	After Decongestion	Baseline	After Decongestion
Predictive Variable							
Age	**Correlation coeff. ***	0.20	0.23	-0.05	- 0.13	0.17	0.18
	p	< 0.05	< 0.05	NS	NS	NS	NS
	N	119	105	118	105	119	104
Height	**Correlation coeff. ***	0.22	0.17	- 0.06	- 0.16	0.19	0.22
	p	< 0.05	NS	NS	NS	< 0.05	< 0.05
	N	115	102	114	102	115	101
BSA	**Correlation coeff. ***	0.25	0.18	- 0.07	- 0.21	0.20	0.23
	p	< 0.01	NS	NS	< 0.05	< 0.05	< 0.05
	N	108	95	107	95	108	94

MCA = minimal cross-sectional area (sum of left and right sides); DMCA = distance of the minimal cross-sectional area from the nostril; VOL = volume between 0 - 3 cm from the nostril (sum of left and right sides); BSA = body surface area; * = Pearson Correlation Coefficient in MCA and VOL, Spearman Correlation Coefficient in DMCA.

body weight and BMI [10]. In conclusion, age and height (or BSA) of a child can be suggested as predictive factors of acoustic values.

Samolinski et al. found that the growth rate of nasal cavities is greater in boys than in girls. The difference between boys and girls was significant when considering the cross-sectional area in the isthmus area [15]. We found no difference in the acoustic values between boys and girls, and other groups concluded the same [5,6,8,13,17].

In previous studies of children there have been some technical problems, mostly related to sound leakage between the nose adaptor and the nostril or in the co-operation with the child [9,12,19]. In this study, we had only minor technical problems and no difficulties with the co-operation. We emphasise the need for strict technical care and a standard way of measuring children with acoustic rhinometry.

CONCLUSION

Acoustic rhinometry is a suitable objective method to examine nasal obstruction in children. It is easy to perform and well tolerated.

In our group of children aged between 7 and 14 years, the mean total MCA was 0.752 cm^2 (SD 0.165), and the mean total volume between 0 - 3 cm was 4.00 cm^3 (SD 0.63) at baseline. After decongestion, the mean total MCA was 0.794 cm^2 (SD 0.162), and the mean total volume was 4.38 cm^3 (SD 0.75).

The difference between the values at baseline and after decongestion is significant. We conclude that acoustic rhinometry is a suitable method to monitor the changes in mucosal swelling in children.

Age and height or BSA of a child can be suggested as predictive factors. There is a significant correlation between age and total MCA, and between height and BSA and anterior nasal volume. There is no difference in the acoustic values between boys and girls in this age group.

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CONFLICT OF INTEREST
None

REFERENCES
1. Cole P. Acoustic rhinometry and rhinomanometry. Rhinology. Suppl 2000; 16: 29-34.
2. Grymer L. Clinical applications of acoustic rhinometry. Rhinology Suppl. 2000; 16: 35-43.
3. Hilberg O, Pedersen OF. Acoustic rhinometry: recommendations for technical specifications and standard operating procedures. Rhinology Suppl. 2000; 16: 3-17.
4. Clement PAR, Gordts F. Consensus report on acoustic rhinometry and rhinomanometry. Rhinology. 2005; 43: 169-179.
5. Jurlina M, Mladina R, Dawidowsky K, Ivankovic D, Bumber Z, Subaric M. Correlation between the minimal cross-sectional area of the nasal cavity and body surface area: preliminary results in normal patients. Am J Rhinol. 2002; 16: 209-213.
6. Millqvist E, Bende M. Reference values for acoustic rhinometry in subjects without nasal symptoms. Am J Rhinol. 1998; 12: 341-343.
7. Haavisto LE, Sipilä JI. Acoustic rhinometry in children: some practical aspects and influence of age and body surface area on results. Am J Rhinol. 2008; 22: 416-419.
8. Qian W, Chen W, Chen JM, Haight J. Acoustic rhinometry in preschool children. Otolaryngol Head Neck Surg. 2007; 137: 39-42.
9. Riechelmann H, Rheinheimer MC, Wolfensberger M. Acoustic rhinometry in pre-school children. Clin Otolaryngol. 1993; 18: 272-277.
10. Miyamoto Y, Takeuchi K, Majima Y. Measurement of nasal patency by acoustic rhinometry in Japanese school children. Auris Nasus Larynx 2009; 36: 406-410.
11. Larsson C, Millqvist E, Bende M. Relationship between subjective nasal stuffiness and nasal patency measured by acoustic rhinometry. Am J Rhinol. 2001; 15: 403-405.
12. Liukkonen K, Virkkula P, Pitkäranta A. Acoustic rhinometry in small children. Rhinology. 2006; 44: 160-163.
13. Straszek SP, Moeller A, Hall GL, Zhang G, Stick SM, Franklin PJ. Reference values for acoustic rhinometry in children from 4 to 13 years old. Am J Rhinol. 2008; 22: 285-229.
14. Straszek SP, Schlunssen V, Sigsgaard T, Pedersen OF. Reference values for acoustic rhinometry in decongested school children and adults: the most sensitive measurement for change in nasal patency. Rhinology. 2007; 45: 36-39.
15. Samolinski BK, Grzanka A, Gotlib T. Changes in nasal cavity dimensions in children and adults by gender and age. Laryngoscope. 2007; 11: 1429-1433.
16. Djupesland P, Pedersen OF. Acoustic rhinometry in infants and children. Rhinology Suppl. 2000; 16: 52-58.
17. Ho W-K, Wei WI, Yuen APW, Chan KI, Hui Y. Measurement of nasal geometry by acoustic rhinometry in normal-breathing Asian children. J Otolaryngol. 1999; 28: 232-237.
18. Millqvist E, Bende M. Two-year follow-up with acoustic rhinometry in children. Am J Rhinol. 2006; 20: 203-205.
19. Haavisto LE, Vahlberg TJ, Sipilä JI. A follow-up study with acoustic rhinometry in children using nasal insulin. Rhinology. 2010; 48: 95-99.

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