

Physical exercise increases nasal patency in asthmatic and atopic preschool children

Lotta E. Haavisto, M.D., Ph.D.,¹ Minna Lukkarinen, M.D.,² Heikki Lukkarinen, M.D., Ph.D.,² Tuomas Jartti, M.D., Ph.D.,² Nikolaos G. Papadopoulos, M.D., Ph.D.,³ and Jukka I. Sipilä, M.D., Ph.D.¹

ABSTRACT

Background: Physical exercise causes a decrease in nasal mucosal congestion and hence an increase in nasal patency. This nasal response has been studied only in adults. A correlation between nasal obstruction and asthma or allergic rhinitis has been previously found. This study evaluates the influences of atopy and asthma on nasal patency and the changes in nasal patency induced by physical exercise in preschool children.

Methods: An 8-minute exercise challenge test was conducted in 31 children aged between 4.1 and 6.4 years: 13 children had asthma, 17 were atopic, and 13 had neither asthma nor atopy. Nasal patency was measured with acoustic rhinometry at baseline and 10 minutes after the exercise.

Results: At baseline, the total acoustic values were 17–25% larger in nonasthmatic children than in asthmatic children. Accordingly, the acoustic values in nonatopic children were 16–35% larger than in atopic children. After physical exercise, there was an overall increase in mean total nasal volume from 2.973 (SD = 0.647) to 3.405 cm³ (SD = 0.705), indicating an improvement of 15% in nasal volume ($p = 0.025$). The increase in nasal patency was similar in asthmatic and nonasthmatic children, as well as in atopic and nonatopic children.

Conclusion: A significant increase in total nasal volume after physical exercise was found in all preschool children. The minimal cross-sectional areas remained smaller in asthmatic and atopic children after exercise, indicating partly irreversible nasal mucosal congestion in these children.

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Physical exercise causes a decrease in nasal mucosal congestion via sympathetic reflexes.^{1–5} This response is maximal at 5–10 minutes and may persist for up to 30 minutes.^{1,2,4} Exercise can be used instead of medical decongestion to decrease the mucosal thickness and to evaluate structural obstruction of the nose.¹ The nasal response seems to be similar in healthy subjects and in patients with rhinitis and asthma,³ but it has only been studied in adults. Knowledge of exercise-induced changes in nasal mucosa in children is lacking.

Chawes *et al.*⁶ found an association between allergic rhinitis and irreversible nasal airway obstruction in children at the age of 6 years, while children with nonallergic rhinitis had a nasal airway patency similar to that of healthy controls. The same group has found an inverse association between decongested nasal patency and blood and nasal eosinophilia.⁷ In adults with asthma, an increased swelling of the nasal mucosa has been shown by Hellgren *et al.*⁸ On the contrary, no difference was found in nasal patency at baseline between asthmatic and control children aged between 2 and 5 years.⁹

Acoustic rhinometry is a useful objective method to evaluate mucosal changes because it gives practical information on the place and degree of nasal obstruction.^{10,11} It is a very suitable method for children because it is rapid, noninvasive, with no side effects, and minimal cooperation is required.^{12–15} This study was designed to evaluate the changes in nasal patency induced by physical exercise in preschool children. Another aim was to evaluate the influence of asthma

and allergy on nasal patency and on the possible changes in patency after exercise in children. Nasal patency was measured with acoustic rhinometry.

MATERIALS AND METHODS

Patients

The study included 32 children aged between 4.1 and 6.4 years (mean, 5.1; SD = 0.7) in Turku University Hospital, Turku, Finland. This is a subgroup of children who were participating in the ongoing follow-up studies of Vinku2 ($n = 25$) or PreDicta ($n = 7$). The former investigates the link between early viral wheeze and development of asthma, and the latter is an European Union-sponsored multicenter study investigating the relationship between respiratory infections and persistence of asthma.

The criteria for exclusion were acute upper respiratory infection or prominent septal deviation detected by anterior rhinoscopy. Written informed consent was obtained from a parent or guardian before the commencement of the study. The study protocol was approved by the Joint Ethical Committees of Turku University and Turku University Hospital, Turku, Finland.

The Definition of Allergy and Asthma

Sensitization against common allergens was tested with a skin-prick test ($n = 7$; wheal diameter 3 mm or more considered as positive reaction for *Dermatophagoides pteronyssinus*, *Alternaria*, grass mix, birch, hazel, Timothy, common reed, mugwort, horse, cat, and dog; ALK-Abelló A/S, Hørsholm, Denmark) or with IgE antibodies ($n = 25$; cut-off level, 0.35 kU/L for codfish, cow's milk, egg, peanut, soybean, wheat, cat, dog, horse, birch, mugwort, Timothy, *Cladosporium herbarum*, and *D. pteronyssinus*; fluoro-enzyme immunoassay, CAP FEIA, Phadiatop Combi; Phadia, Uppsala, Sweden). Children were considered atopic if they had a positive reaction to any of these allergens.

The diagnosis of current asthma at the study visit was based either on typical symptoms fulfilling National Asthma Education and Prevention Program criteria during the preceding year^{16,17} and/or on hyperreactivity in lung function testing: bronchodilator response (in the impulse oscillometry of $\geq 35\%$ decrease in respiratory resistance at 5 Hz [Rrs5]¹⁸ or in the spirometry of $\geq 15\%$ increase in forced expiratory volume at 1 second after inhalation of 300 μ g of salbutamol¹⁶),

From the Departments of ¹Otorhinolaryngology and ²Pediatrics, Turku University Hospital, Turku, Finland, and ³Department of Allergy, Second Pediatric Clinic, University of Athens, Athens, Greece

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Address correspondence to Lotta E. Haavisto, M.D., Ph.D., Department of Otorhinolaryngology, Turku University Hospital, P.O. Box 52, 20521 Turku, Finland
E-mail address: lotta.haavisto@tyks.fi

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Table 1 Subject characteristics

	<i>n</i>	Age (yr)		Height (cm)		Weight (kg)	
		Mean	SD	Mean	SD	Mean	SD
Whole group	31	5.15	0.70	111.2	4.96	19.7	2.26
Subgroups according to asthma and atopy							
No asthma and no atopy	13 (42%)	4.86	0.66	109.7	5.07	19.4	2.24
Atopy and no asthma	5 (16%)	5.26	0.47	111.7	4.72	20.0	1.25
Asthma and no atopy	1 (3%)	4.45	—	109.2	—	18.4	—
Asthma and atopy	12 (39%)	5.47	0.72	112.7	5.04	20.1	2.72

or on positive exercise challenge test (an increase of $\geq 35\%$ in Rrs⁵¹⁹ or a decrease of $\geq 15\%$ in forced expiratory volume at 1 second ¹⁶ after a free-running test).

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 Standardization of Acoustic Rhinometry.¹⁵ The equipment was checked with an artificial nose delivered by the manufacturer every day before the first measurement. All of the measurements were performed by the same author (L.H.).

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

The first measurement (baseline) was taken after acclimatization to the room temperature for 15–20 minutes. After baseline measurements, the exercise challenge was performed (later in text). The measurements were repeated 10 minutes after exercise.

The acoustic values of special interest were the first two total minimal cross-sectional areas (TMCA1 and TMCA2, corresponding to the first and the second notch in the curve, as the sum of both sides of the nose), the total smallest minimal cross-sectional area (TMCA as the sum of both sides of the nose), and the total nasal cavity volume 0–3 cm from the nostril (TVOL as the sum of both sides of the nose). In addition, unilateral values measured separately from the narrow and wide sides of the nose were used for further calculations (MCA1, MCA2, MCA, and VOL).

Exercise Challenge

The exercise challenge was performed as a free-running test especially designed to assess bronchial hyperreactivity in asthmatic children.^{19,20} The children were urged to run for 6–8 minutes at an exercise level where the heart rate was held at 85–90% of their estimated maximum heart rate, assessed with a heart rate monitor. Air temperature was measured, and the exercise test was performed outside when the air temperature was $\geq 5^{\circ}\text{C}$, otherwise it was performed inside. The challenge was performed under the supervision of a pediatrician.

Statistical Analysis

Shapiro-Wilk test was used to determine the normality of the data. The Spearman correlation coefficients were calculated based on the nonnormality. The differences between the two individual groups and between the two measurements at baseline and after exercise were tested with the Wilcoxon rank sum test with skewed distributions. The value of $p < 0.05$ was considered significant. Statistical analyses were conducted with SAS System for Windows, Version 9.3 (SAS Institute, Inc., Cary, NC) by a professional biostatistician.

RESULTS

Study Population

The study included 32 children aged between 4.1 and 6.4 years (mean, 5.1; SD = 0.7). One child was excluded because she refused to do the exercise test. The final group of 31 children included 10 girls and 21 boys. At the study visit, 12 (39%) of the study children fulfilled the criterion of both current asthma and atopy; 5 (16%) had only atopy, 1 (3%) had only asthma, and 13 (42%) had neither asthma nor atopy. Eight children were reported to have either long-standing rhinitis or obstruction of the nose, but they had had a period of medical washout for at least 4 weeks. The subject characteristics are summarized in Table 1.

Baseline Values

At baseline, the mean TMCA1 was 0.650 cm^2 (SD = 0.158), the mean TMCA2 was 0.838 cm^2 (SD = 0.452), the mean TMCA was 0.575 cm^2 (SD = 0.151), and the mean TVOL was 2.973 cm^3 (SD = 0.647) in the whole group of children.

The Influence of Asthma on Baseline Values. A significant negative correlation was found between asthma and TMCA1 ($r = -0.37$; $p = 0.041$) and TMCA ($r = -0.39$; $p = 0.016$) in total values. In addition, a negative correlation was found between asthma and MCA1 ($r = -0.53$; $p = 0.002$), MCA ($r = -0.41$; $p = 0.023$), and VOL ($r = 0.42$; $p = 0.028$) on the narrow side of the nose, and between asthma and MCA ($r = -0.42$; $p = 0.018$) on the wide side of the nose.

At baseline, the acoustic values in nonasthmatic children were larger than in asthmatic children. In total values the difference in mean TMCA1 was 19% (0.697 cm^2 versus 0.585 cm^2 ; $p = 0.043$), difference in mean TMCA2 was 20% (0.902 cm^2 versus 0.749 cm^2 ; $p = 0.54$), difference in mean TMCA was 25% (0.627 cm^2 versus 0.502 cm^2 ; $p = 0.024$), and difference in mean TVOL was 17% (3.176 cm^3 versus 2.703 cm^3 ; $p = 0.22$). For unilateral values, a statistically significant difference was found more frequently on the narrow side of the nose than on the wide side. All of the acoustic values and the differences between asthmatic and nonasthmatic children are presented in Table 2 and the boxplot for the TMCA is shown in Fig. 1.

The Influence of Atopy on Baseline Values. A significant negative correlation was found between atopy and TMCA ($r = -0.42$; $p = 0.020$) and TVOL ($r = -0.44$; $p = 0.020$) in total values. In addition, a negative correlation was found between atopy and MCA1 ($r = -0.48$; $p = 0.0059$), MCA ($r = -0.48$; $p = 0.017$), and VOL ($r = -0.55$; $p = 0.0027$) on the narrow side of the nose and between MCA ($r = -0.40$; $p = 0.024$) and VOL ($r = -0.38$; $p = 0.044$) on the wide side of the nose.

At baseline, the total values were 16–35% larger in nonatopic children, but the only statistically significant difference was found in mean TMCA (0.643 cm^2 versus 0.519 cm^2 ; $p = 0.031$). The acoustic values in nonatopic children were significantly larger than in atopic children more frequently on the narrow side of the nose. All of the values and the differences between atopic and nonatopic children are presented in Table 2 and the boxplot for the TMCA is shown in Fig. 1.

Table 2 Acoustic values at baseline in asthmatic and nonasthmatic children and in atopic and nonatopic children

Acoustic Values	Asthma			No Asthma			Diff.	Percent	p Value
	n	Mean	SD	n	Mean	SD			
Total values									
TMCA1 (cm ²)	13	0.585	0.120	18	0.697	0.168	0.112	19	0.043
TMCA2 (cm ²)	13	0.749	0.351	18	0.902	0.320	0.153	20	0.540
TMCA (cm ²)	13	0.502	0.096	18	0.627	0.163	0.125	25	0.024
TVOL 0–3 (cm ³)	12	2.703	0.459	16	3.176	0.705	0.473	17	0.217
Narrow side									
MCA1 (cm ²)	13	0.242	0.045	18	0.316	0.095	0.074	31	0.007
MCA2 (cm ²)	13	0.336	0.235	18	0.364	0.174	0.028	8	0.171
MCA (cm ²)	13	0.210	0.051	18	0.262	0.090	0.052	25	0.035
VOL 0–3 (cm ³)	12	1.162	0.237	16	1.371	0.279	0.209	18	0.042
Wide side									
MCA1 (cm ²)	13	0.343	0.084	17	0.404	0.082	0.061	18	0.075
MCA2 (cm ²)	12	0.448	0.207	16	0.605	0.358	0.157	35	0.285
MCA (cm ²)	13	0.292	0.055	18	0.366	0.087	0.075	25	0.029
VOL 0–3 (cm ³)	12	1.541	0.293	16	1.804	0.460	0.263	17	0.247
		Atopy			No Atopy				
Total values									
TMCA1 (cm ²)	17	0.605	0.144	14	0.704	0.162	0.099	16	0.098
TMCA2 (cm ²)	17	0.723	0.324	14	0.977	0.551	0.254	35	0.200
TMCA (cm ²)	17	0.519	0.123	14	0.643	0.158	0.124	23	0.031
TVOL 0–3 (cm ³)	16	2.726	0.539	12	3.303	0.651	0.577	21	0.137
Narrow side									
MCA1 (cm ²)	17	0.249	0.080	14	0.327	0.073	0.031	27	0.014
MCA2 (cm ²)	17	0.334	0.207	14	0.374	0.193	0.040	12	0.235
MCA (cm ²)	17	0.213	0.069	14	0.273	0.081	0.060	28	0.028
VOL 0–3 (cm ³)	16	1.156	0.226	12	1.449	0.257	0.293	25	0.009
Wide side									
MCA1 (cm ²)	17	0.356	0.081	13	0.405	0.090	0.049	14	0.176
MCA2 (cm ²)	15	0.441	0.198	13	0.649	0.378	0.208	47	0.152
MCA (cm ²)	17	0.306	0.066	14	0.370	0.090	0.064	21	0.330
VOL 0–3 (cm ³)	16	1.570	0.369	12	1.853	0.426	0.283	18	0.059

Value of $p < 0.05$ is considered significant.

TMCA1 = total minimal cross-sectional area at the first notch as the sum of both sides; TMCA2 = total minimal cross-sectional area at the second notch as the sum of both sides; TMCA = total minimal cross-sectional area as a sum of both sides; TVOL 0–3 = total volume between 0 and 3 cm from the nostril as the sum of both sides; MCA1 = unilateral minimal cross-sectional area at the first notch (narrow or wide side); MCA2 = unilateral minimal cross-sectional area at the second notch (narrow or wide side); MCA = unilateral minimal cross-sectional area (narrow or wide side); VOL 0–3 = unilateral volume between 0 and 3 cm from the nostril (narrow or wide side); Diff. = difference between groups with and without atopy or asthma.

The Combined Influence of Asthma and Atopy on Baseline Values. To further evaluate the roles of asthma and atopy on the acoustic values, comparisons were made to find the possible differences between those children who had both asthma and atopy ($n = 12$), those who were only atopic ($n = 5$), and those who had neither asthma nor atopy ($n = 13$). According to overall comparisons, a significant difference between the three groups in total values was found in TMCA ($p = 0.032$). In further calculations, a significant difference was found between those with both asthma and atopy, in comparison with those with neither asthma nor atopy in mean TMCA (0.504 cm² versus 0.655 cm²; $p = 0.024$).

In unilateral values, the overall comparisons found differences on the narrow side of the nose in MCA1 ($p = 0.0071$), in MCA ($p = 0.034$), and in VOL ($p = 0.018$). In further calculations, a significant difference was found between those with both asthma and atopy, in comparison with those with neither asthma nor atopy in mean MCA1 (0.247 cm² versus 0.338 cm²; $p = 0.0032$), in mean MCA (0.213 cm² versus 0.280 cm²; $p = 0.018$), and in mean VOL (1.131 cm³ versus 1.445 cm³; $p = 0.012$). Respectively, a significant difference between those two subgroups was found on the wide side of the nose in mean MCA (0.292 cm² versus 0.375 cm²; $p = 0.028$). No other statistically significant differences between any of the subgroups were found.

The Effect of Physical Exercise

After physical exercise, there was a significant change in mean TVOL from 2.973 to 3.405 cm³ ($p = 0.025$) in the whole group, indicating an improvement of 15% in nasal volume. The change in mean TMCA1 was +2% (from 0.650 to 0.673 cm²; $p = 0.571$), change in mean TMCA2 was +38% (from 0.838 to 1.156 cm²; $p = 0.17$), and change in mean TMCA was +6% (from 0.575 to 0.610 cm²; $p = 0.36$). In addition, a significant change was found in mean VOL on the wide side of the nose, from 1.691 to 1.959 cm³ ($p = 0.022$). The changes in other unilateral values were not significant.

The Influence of Asthma and Atopy on the Change in Acoustic Values after Exercise. There was no difference in the change in acoustic values after exercise between asthmatic and nonasthmatic children, or between atopic and nonatopic children. Accordingly, the effect of exercise was the same in the three subgroups (asthma with atopy, only atopy, and no asthma and no atopy).

The difference between asthmatic and nonasthmatic children remained the same after exercise. A significant negative correlation was found between asthma and TMCA1 ($r = -0.61$; $p = 0.0004$) and TMCA ($r = -0.49$; $p = 0.0048$). Similarly, a significant negative correlation was found between atopy and TMCA1 ($r = -0.54$; $p =$

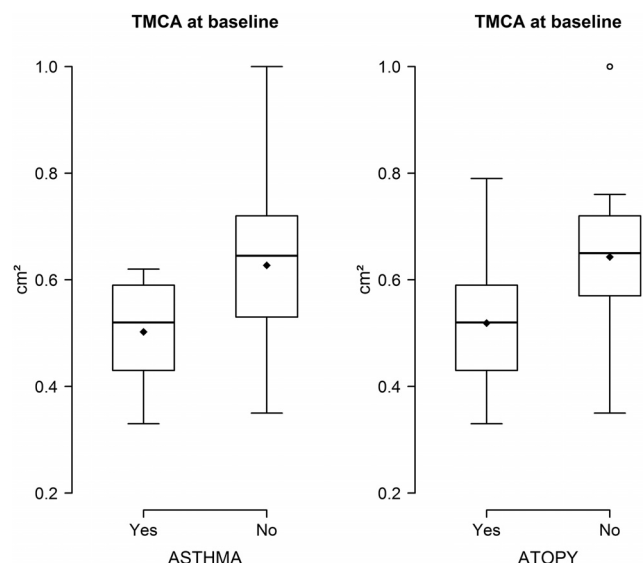


Figure 1. Boxplot of total minimal cross-sectional area values at baseline in asthmatic and nonasthmatic children, as well as in atopic and nonatopic children. TMCA, total minimal cross-sectional area as a sum of left and right side (cm²). Symbols in the boxplot: box = interquartile range (range between 25th and 75th percentile); diamond = mean; horizontal line = median; circle = outlier.

0.0022) and TMCA ($r = -0.63$; $p = 0.0002$). The total acoustic values at baseline and 10 minutes after exercise for the whole group, as well as for subgroups, for asthmatic and atopic children, are summarized in Table 3. The boxplot for the TMCA after the physical exercise are presented in Fig. 2.

DISCUSSION

This was the first time the nasal decongestive reaction to physical exercise has been evaluated in children. This well-known reaction in nasal patency is based on sympathetic reflexes and is in proportion to exertion or the duration of the exercise.^{1-3,21}

The strength of our study was that the exercise was performed in a standard and validated way, with the level of heart rate being kept at 85–90% of children's estimated maximum during running. The nasal reaction was measured 10 minutes after exercise. The reaction has been shown to reach maximum level in adults at 5–10 minutes and may persist for up to 30 minutes.^{1-2,4,21,22}

The overall increase in total anterior volume after exercise was 15%. In our previous study in school children aged between 6 and 14 years we achieved a significant change of 10% in total volume with a xylometazoline spray.¹² Similarly, the increase in MCA with decongestant spray in our former study was 6%, and in this study the exercise-induced change in TMCA was identically 6%. To evaluate mucosal changes, the anterior values of volume or MCAs have been recommended, because the maximum congestive capacity is located at the anterior end of the inferior turbinate.¹⁵ Following this recommendation, we used the volume between 0 and 3 cm from the nostril in preschool children. In adults, the volume between 0 and 6 cm was increased as much as 33–42% after exercise.²¹

Table 3 Total acoustic values at baseline and after exercise

Acoustic Values	Baseline			After Exercise (10 min)		
	<i>n</i>	Mean	SD	<i>n</i>	Mean	SD
Whole group						
TMCA1 (cm ²)	31	0.650	0.158	31	0.673	0.121
TMCA2 (cm ²)	31	0.838	0.452	30	1.156	0.795
TMCA (cm ²)	31	0.575	0.151	31	0.610	0.138
TVOL 0–3 (cm ³)	28	2.973	0.647	28	3.405	0.705
Asthma*						
TMCA1 (cm ²)	13	0.585	0.120	13	0.592	0.077
TMCA2 (cm ²)	13	0.749	0.351	12	1.039	0.833
TMCA (cm ²)	13	0.502	0.096	13	0.535	0.097
TVOL 0–3 (cm ³)	12	2.703	0.459	12	3.223	0.648
No asthma*						
TMCA1 (cm ²)	18	0.697	0.168	17	0.735	0.113
TMCA2 (cm ²)	18	0.902	0.512	18	1.233	0.783
TMCA (cm ²)	18	0.627	0.163	18	0.664	0.140
TVOL 0–3 (cm ³)	16	3.176	0.705	16	3.541	0.735
Atopy#						
TMCA1 (cm ²)	17	0.605	0.144	17	0.620	0.105
TMCA2 (cm ²)	17	0.723	0.324	16	0.991	0.781
TMCA (cm ²)	17	0.519	0.123	17	0.538	0.092
TVOL 0–3 (cm ³)	16	2.726	0.539	16	3.198	0.659
No atopy#						
TMCA1 (cm ²)	15	0.681	0.178	13	0.743	0.106
TMCA2 (cm ²)	15	0.961	0.534	14	1.344	0.796
TMCA (cm ²)	15	0.625	0.167	14	0.698	0.136
TVOL 0–3 (cm ³)	13	3.201	0.723	12	3.681	0.693

*No difference in the change of acoustic values between asthmatic and nonasthmatic children.

#No difference in the change of acoustic values between atopic and nonatopic children.

TMCA1 = total minimal cross-sectional area at the first notch as the sum of left and right sides; TMCA2 = total minimal cross-sectional area at the second notch as the sum of left and right sides; TMCA = total minimal cross-sectional area as a sum of left and right sides; TVOL 0–3 = total volume between 0 and 3 cm from the nostril as the sum of left and right sides.

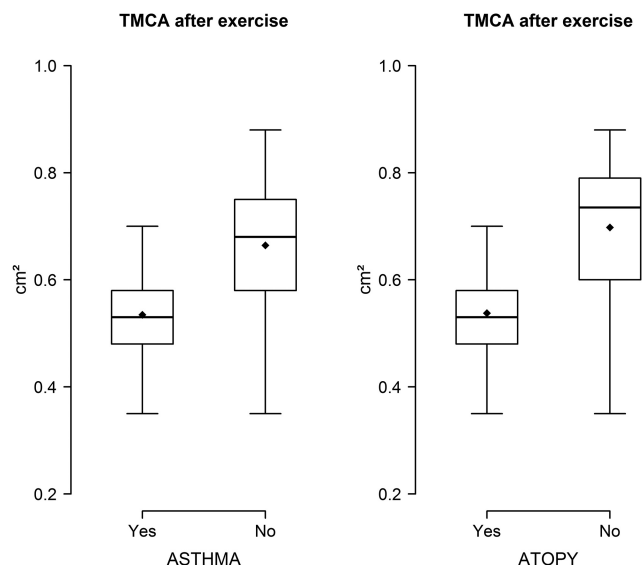


Figure 2. Boxplot analysis of TMCA values 10 minutes after physical exercise in asthmatic and nonasthmatic children, as well as in atopic and nonatopic children. TMCA = total minimal cross-sectional area as a sum of left and right side (cm²). Symbols in the boxplot: box = interquartile range (range between 25th and 75th percentile); diamond = mean; horizontal line = median; circle = outlier.

In our study the decongestion of nasal mucosa induced by exercise was similar in asthmatic and nonasthmatic children, as well as in atopic and nonatopic children. Similarly, Serra-Batles *et al.*³ found no difference in nasal reaction measured with rhinomanometry in adult patients with asthma or rhinitis in comparison with healthy controls. Valero *et al.*⁴ used acoustic rhinometry to show a marked increase in nasal patency in asthmatic adults after exercise, but there was no control group with healthy adults. In their study, the mucosal reaction persisted for as long as 50 minutes. In our study with preschool children the follow-up period was only 10 minutes, and the maximal duration of the response was not evaluated.

Rhinitis and nasal obstruction are common comorbidities in patients with asthma.^{8,9,23,24} An increased mucosal swelling evaluated with acoustic rhinometry has been found in adult patients with asthma compared with healthy controls.⁸ On the contrary, Steinsvåg *et al.*⁹ found no difference in acoustic values, although visual analog scale for nasal blockage reported by parents was higher in small asthmatic children compared with controls.

We found a negative correlation between acoustic values and asthma, as well as between acoustic values and atopy in children between 4 and 6 years of age. At baseline, the total acoustic values were 17–25% larger in nonasthmatic children than in asthmatic children, and 16–35% larger in nonatopic children than in the atopic children. The role of asthma and allergy in nasal obstruction at baseline seems evident.

Furthermore, the influence of asthma and atopy on nasal obstruction remained after the opening effect of physical exercise. The capacity of nasal mucosal decongestion after exercise was similar in asthmatic and atopic children in comparison with those with no asthma or atopy.

Chawes *et al.*⁶ evaluated the role of allergy and nasal eosinophilia in nasal dimensions in 6-year-old children. They found an association between allergic rhinitis and irreversible nasal airway obstruction and suspected chronic inflammation and structural remodeling of the nasal mucosa. In the same way, our findings indicate that the nasal congestion in young atopic children may be partly irreversible. We have additionally shown that this permanent obstruction is similar

even in asthmatic children. It has been stated that the hyperresponsiveness of nasal congestive reflexes in subjects with allergic rhinitis may be caused both by local actions in the mucosal membrane as well as by nasonasal reflexes.²⁵ According to our results, we suspect that some kind of structural changes may be involved. However, more research is needed to find the reason for the persistent nasal obstruction in asthmatic and atopic children.

CONCLUSIONS

In conclusion, a significant increase of 15% in total nasal volume after physical exercise was found in preschool children aged between 4 and 6 years. This change was similarly found in all children.

The acoustic values were larger in nonasthmatic children than in asthmatic children and in nonatopic children than in atopic children at baseline. Moreover, the MCAs remained smaller in asthmatic and atopic children after exercise, indicating partly irreversible nasal mucosal congestion in these children.

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