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Upper airway sagittal dimensions in children with hyper-divergent class II/1 malocclusion

Сагиталне димензије горњих дисајних путева код деце са хипердивергентном малоклузијом класе II/1

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SUMMARY

Introduction/Objective Upper air dimensions are associated with morphological facial features. The objective of study is to test the hypothesis that the sagittal size of the upper respiratory pathways in children aged 8–12 years with hyperdivergent Class II/1 malocclusion is smaller compared to the general population of the same age. This may be associated with an increased risk of developing obstructive sleep apnea syndrome in these individuals later in life.

Methods Using profile teleradiograms of 31 children average age being 9.02 ± 1.00 years with hyperdivergent Class II/1 malocclusion, sagittal dimensions of the pharyngeal respiratory pathway at the levels of naso-, oro-, and hypopharynx were measured. These dimensions were compared with measurements from 35 children with an average age of 8.97 ± 0.60 years with other types of malocclusions.

Results Statistically significant smaller sagittal dimensions of the upper respiratory pathways were found in children with hyperdivergent Class II/1 malocclusion compared to the general population of the same age at all three measured levels.

Conclusion The hypothesis was confirmed that in children with hyperdivergent Class II/1 malocclusion, the dimensions of the pharyngeal respiratory pathways are significantly smaller compared to the general population of the same age. The width of the oropharynx contributes most to this difference, followed by the width of the nasopharynx, with the least contribution from the hypopharynx.

Keywords: upper airway size; pharynx; distal occlusion; malocclusion

САЖЕТАК

Увод/Циљ Димензије фарингеалних дисајних путева се доводе у везу са морфолоgijom лица. Циљ рада је да испита хипотезу да је сагитална величина горњих дисајних путева код деце старости 8 до 12 година са малоклузијом хипердивергентне класе II/1 мања у поређењу са општом популацијом истог узраста.

Методе На профилним телерадиограмима 31 детета старости 9,02 ± 1,00 година са хипердивергентном малоклузијом класе II/1 измерене су сагиталне димензије фарингеалног дисајног пута на нивоима назо-, оро- и хипофаринкса и упоређене са димензијама измереним код 35 деце старости 8,97 ± 0,60 година са другим облицима малоклузија.

Резултати Пронађене су статистички значајно уже сагиталне димензије горњих дисајних путева код деце са малоклузијом хипердивергентне класе II/1 у поређењу са општом популацијом истог узраста, на сва три мерена нивоа.

Закључак Потврђена је хипотеза да су код деце са малоклузијом хипердивергентне класе II/1 димензије фарингеалних дисајних путева значајно мање у поређењу са општом популацијом истог узраста. Највећи допринос разлици даје ширина орофаринкса, следи ширина назофаринкса, са најмањим доприносом хипофаринкса.

Кључне речи: величина горњих дисајних путева; фаринкс; дистална оклузија; малоклузија

INTRODUCTION

The pharynx represents the intersection of the aerodigestive tracts. Diverse morphological types and their corresponding growth patterns can be identified within the pharynx, similar to the face. The posterior cranial base occupies a diagonal position within the cranium and constitutes the posterior wall of the bony nasopharynx. Consequently, its growth will influence the pharynx's horizontal and vertical dimensions [1]. Individuals with dolichocephalic growth patterns are commonly associated with an inclination to develop a more acute cranial base angle [2] and posterior position of the tongue, thus reducing sagittal dimensions of the upper respiratory tracts [3].

In nasal-breathing participants the sagittal breadth of the nasopharynx appears to be largely independent of anterior dentofacial dimensions [1]. Higher correlations found in mouth breathers suggest that limited patency of the upper airways has physiological implications linked to changes in dentofacial morphology [4, 5].

Factors contributing to the narrowing of the upper airways are believed to be both reduced pharyngeal muscle tone and unfavourable anatomical relations in the pharynx and surrounding structures, as airway constrictions [6].

El and Palomo's three-dimensional analysis of pharyngeal airways finds a significantly narrower oropharyngeal airway in Class II participants compared to those in Classes I and III. A more constricted nasopharyngeal passage is observed in Class II participants relative to those in Class I [7, 8]. All authors concur that pharyngeal dimensions are diminished in Class II skeletal patterns, irrespective of the patient's position during examination (upright or supine) and regardless of the imaging technique employed [6, 9, 10].

In examination of the regions of the upper respiratory tract susceptible to collapse based on craniofacial morphology, Alhammadi builds on established views that retrognathism, micrognathism and elongated face, along with a shortened length and angle of the anterior cranial base, increased ANB angle, influence pharyngeal airway constrictions. Nevertheless, he contends that constriction sites depend on specific craniofacial morphology parameters or their combinations, and that multi-site collapses are not uncommon [11, 12].

In Caucasian individuals with narrowed upper respiratory tracts, a retrognathic face is observed. The maxilla and an underdeveloped mandible are retrusive, anterior facial height is increased, occlusal and mandibular plane angles are augmented, upper and lower molars are hypererupted, incisors proclined, and incisal overbite reduced [13, 14].

Vučinić et al., analysing morphological features of the upper jaw in mouth-breathing children, identified peculiarities that also exist in individuals with manifesting obstructive sleep apnea syndrome (OSA), such as narrow maxilla, underdeveloped apical bases, and a reduced inclination of the upper jaw plane to the anterior cranial base [15]. OSA represents a broad spectrum of disorders primarily manifested by snoring, witnessed apnea and daytime sleepiness [16]. This underscores the need for early detection of factors that can contribute to morphofunctional narrowing of the airways to potentially influence them during growth [17]. Tangugsorn and colleagues recommend lateral cephalogram analysis in assessing areas of pharyngeal airway constriction [18].

This study aims to ascertain the dimensions of orofacial structures in the upper respiratory tract region during growth and development, and potential deviations which, in later life stages, could contribute to respiratory disturbances and OSA. Furthermore, it aims to assess opportunities for early intervention using functional orthodontics.

Research hypothesis: the upper respiratory tracts are significantly narrower in at least one sagittal dimension in children with hyperdivergent skeletal Class II/1 compared to children with normative skeletal relationships or the remainder of the population.

METHODS

The study was conducted at the Department of Orthodontics, Clinic of Dentistry of Vojvodina, involving a total of 66 children. They were divided into two primary groups based on facial morphology. The research entailed examining and comparing the sagittal dimensions of the upper respiratory pathways in children with a distal position of the lower jaw and children without this malocclusion from the general population.

Selection of participants

The subjects were children aged 8-12 years with a retrognathic face of Class II and protrusion and proclination of the upper incisors (Class II/1). This was routinely determined for each patient through the analysis of lateral cephalometric radiographs as part of the diagnostic methods employed to determine the type and severity of stomatognathic development disorders.

Only those participants whose parents gave informed consent were included in the study. Given that a narrow upper respiratory pathway is associated with an increased vertical dimension of the lower part of the face, an additional criterion for patient selection was vertical growth of orofacial structures (Björk polygon greater than 396° and Jaraback index less than 62%). From the patient database of the Department of Orthodontics, 31 patients with characteristics corresponding to the research topic were identified, who were either undergoing or about to undergo treatment with functional devices of.

The experimental group consisted of 16 girls (51.61%) and 15 boys (48.39%), with an average age of 9.02 ± 1.00 years (range 8-11.3 years).

The control group, consisted of 35 children with an average age similar to the experimental sample (8.97 ± 0.6 years). They were randomly selected among patients of the Department of Orthodontics at the Clinic of Dentistry of Vojvodina to closely represent the craniofacio-cervical morphological characteristics of the general population of the corresponding age and growth stage.

Patients with facial morphology matching the experimental group could not be part of the control group.

Exclusion criteria for both groups included reduced airway patency due to hypertrophic adenoid vegetation, cleft lip and palate, hypo- and hyperdontia, severe congenital syndromes like Pierre Robin, Crouzon, Apert, and Treacher-Collins syndromes.

Methodology

The study utilized cephalometric radiographic examination of patient profile images, employing standard analyses developed for orthodontic diagnostics, supplemented by measurements of upper respiratory pathways.

Lateral cephalometric radiographs were taken at the X-ray department of the Clinic of Dentistry of Vojvodina using a standard technique under uniform conditions on the Orthophos XG5 device (Sirona Dental GmbH, Wals bei Salzburg, Austria). Analyses of the obtained cephalometric radiographs were performed using the OnyxCeph software (Image Instruments GmbH, Chemnitz, Germany). Data were entered into tables adapted to the research topic using MS Office Excel 2007 software.

In addition to standard cephalometric parameters—angles of maxillary prognathism (SNA), mandibular prognathism (SNB), and the angle of skeletal jaw relationship in the sagittal dimension (ANB)—the dimensions of the upper respiratory pathways were determined.

Sagittal diameter dimensions of the upper respiratory pathways were determined by measuring the following distances:

1. Distance between the posterior nasal spine (snp) and the intersection point of the line from the posterior nasal spine to the basion (snp-Ba) with the posterior pharyngeal wall, representing the width of the nasopharynx (UPW).

2. Distance between the uvula's tip and the nearest point on the pharyngeal posterior wall, representing the width of the oropharynx (MPW).

3. Distance between the vallecula and the nearest point on the pharyngeal posterior wall, representing the width of the hypopharynx (LPW) (adopted from Tangugsorn et al. 1995 [17]) (Figure 1).

Reliability

Duplicate measurements were undertaken for all variables. These measurements were taken two weeks apart by the same examiner on a random sample of 20 cephalograms. Systematic errors between the two measurements were assessed using a paired t-test for $p<0.05$. No significant differences were identified for any hard or soft tissue variables between the two datasets. The error variance was calculated according to Dahlberg's formula.

Statistical methods

This paper presents descriptive parameters: mean, standard deviation (Sd), minimum and maximum of all values, coefficient of variation (Cv), confidence interval, and the Kolmogorov-Smirnov test value.

Multivariate procedures MANOVA and discriminant analysis were used. Univariate procedures applied included ANOVA and the t-test.

The application of procedures that provide a contribution measure gives a new dimension to this research. By calculating the discrimination coefficient, we can identify the features that determine the specificity of the subsamples and the features that need to be excluded from further processing, i.e., a reduction of the observed space is performed. The representation of subsample homogeneity estimates, the distance between them, and cluster analysis aim to study the observed phenomenon thoroughly.

Data are presented in tabular form.

Research was approved by Ethical Committee of Dental Clinic of Vojvodina (01-107/8-2012).

RESULTS

Basic characteristics of the sample (Experimental and Control Group)

The experimental group included 31 participants (16 girls (51.61%) and 15 boys (48.39%)), with an average age of 9.02 ± 1.00 years (range 8-11.3 years).

In the experimental group, no gender-based differences were observed in age (p = 0.1381), nor in the parameters used as inclusion criteria: Björk's polygon (p = 0.1771), the lower face index (p = 0.3423), and the size of the ANB angle (p = 0.3790). Thus, participant data were processed regardless of gender.

The control group consisted of 35 patients (21 girls (60%) and 14 boys (40%)), with an average age of 8.97 ± 0.60 years (range 8–9.9 years).

In the control group, no gender-based differences were observed in age (p = 0.2148) or in the parameters used as inclusion criteria: Björk's polygon (p = 0.7408), the lower face index (p = 0.9132), and the size of the ANB angle (p = 0.9426). Thus, participant data were processed regardless of gender.

Basic parameters of the upper respiratory pathway dimensions relative to the groups

Central and dispersion parameters for the dimensions of the upper airways of the experimental group of 31 participants and the control group of 35 participants are shown in Table 1. and Table 2., respectively.

Differences between the experimental and control groups concerning the dimensions of the upper respiratory pathways

The test of the assertion if there is a significant difference between participant groups concerning the dimensions of the upper respiratory pathways was done. Group differences are shown in Table 3, whereas individual differences are shown in Table 4.

The discrimination coefficient suggests that the most significant contribution to discrimination between participant groups concerning the dimensions of the upper respiratory pathways is, namely, the difference in the following:

1. Oropharynx width (0.180),
2. Nasopharynx width (0.176),
3. Hypopharynx width (0.017).

Characteristics and homogeneity of participant groups concerning the dimensions of the upper respiratory pathways

Based on previous considerations and sample analysis of 66 participants, in accordance with the applied methodology, the next step in the research is determining the characteristics and homogeneity of each participant group and the distance between them.

The fact that $p = 0.000$ of the discriminant analysis indicates there's a clear boundary between participant groups, i.e., it's possible to determine the characteristics of each group concerning the dimensions of the upperairways. Characteristics and homogeneity of participant groups concerning the dimensions of the upper airways are shown in Table 5, whereas distance (Mahalanobis) between participant groups concerning the dimensions of the upper respiratory pathways is shown in Table 6.

DISCUSSION

The average values of the sagittal diameter of the nasopharynx in the experimental group (16.26 ± 3.72 mm) and control group (19.27 ± 4.18 mm), as well as the oropharynx (8.19 ± 2.30 mm and 10.33 ± 2.03 mm respectively) and hypopharynx (12.03 ± 3.01 mm and 13.97 ± 3.27 mm respectively), were statistically compared.

The results of this study, based on the values of p = 0.000 (MANOVA analysis) and p = 0.000 (discriminant analysis), indicate a difference and a clearly defined boundary between the groups of participants.

The statistically determined $p<0.05$ shows that there is a significant difference between the groups of participants in the width of the nasopharynx (0.003), the width of the oropharynx (0.000), and the width of the hypopharynx (0.015). This is consistent with previous studies by de Oliveira et al. in a sample of adolescents [14], as well as Alhammadi et al. in an adult sample [12].

Based on the previous results, it can be said that the pharyngeal airways are statistically significantly narrower at all three measured levels.

The values of the upper respiratory tract widths were statistically significantly different, and there is a clearly defined boundary between the experimental and control groups if the diameters of the upper respiratory pathways are viewed as a group of statistical features, i.e., collectively approaching the diameters of the nasopharynx, oropharynx, and hypopharynx.

The largest individual contribution to the difference was found at the level of the oropharynx, followed by the nasopharynx, and then the hypopharynx.

When viewed separately, the values of the widths of the nasopharynx, oropharynx, and hypopharynx also show a statistically significant difference and a clear boundary between the experimental and control groups. With the presence of a boundary, it is possible to determine the characteristics of each group concerning the dimensions of the upper respiratory pathways at the initial measurement. The characteristic of each subsample group is most defined by the width of the oropharynx because its contribution to the characteristics is 48.26%, followed by the width of the nasopharynx (47.18%), and the width of the hypopharynx (4.56%).

Based on the measured values and their statistical processing, it can be said for the experimental group that the dimensions of the upper respiratory pathways at all three levels are smaller, while for the control group, they are larger at all three levels. The finding that the pharyngeal respiratory pathways in retrognathic participants of class II malocclusion are narrower compared to the respiratory pathways in the general population is consistent with previous research referenced in this paper.

Similar findings were also observed by El and Palomo when measuring the volume of the upper respiratory pathways in skeletal classes I, II, and III. There was a significant difference in the size of the respiratory pathways in class II, while in class III, these differences were not statistically significant [7].

In contrast, Lowe did not find significant differences between people with obstructive sleep apnea, during sleep, concerning the malocclusion class [13].

Pirilä-Parkkinen et al., in a sample of children with an average age of 7.3 ± 1.43 years, found that the greatest narrowness is at the level of the nasopharynx [19]. It should be noted that Taylor et al. found that at this age, there has not yet been an involution of adenoid tissue that can affect the apparent narrowing in that part [20].

For correct dimensions of the upper airways of children with yet uncompleted growth, there is scant data, further complicated by a large number of etiological factors that can contribute to the occurrence of narrowing, as well as different places where narrowing can occur. In their research on the connection between facial morphology growth and chronological age in preschool children with obstructive sleep apnea, Kawashima et al. indicate that adenoid tissue begins to regress between the ages of 8 and 10 [21].

Oh et al., in a sample of 60 healthy children, found that children with class II have a more posterior orientation and a smaller volume of pharyngeal airways than healthy children with malocclusions of classes I and III. The key factor in determining the shape of the pharyngeal respiratory pathway is its inclination and head position [22].

The homogeneity of the experimental group is 70.97%, and the control group is 80.00%.

The characteristics of the experimental group are held by 22 out of 31 participants, with a homogeneity of 70.97% (expressed), and the characteristics of the control group are present in 28 out of 35 participants, with a homogeneity of 80.0% (expressed).

In addition to the inclination and size of the pharynx, adjacent structures are related to the reduction of available space for the accommodation of soft tissue structures of the orofacial system, especially the tongue, due to the distal position of the mandible and preventing its action on the proper development of the jaws [14]. Vučinić et al. found that narrowed pharyngeal dimensions are associated with the maxillary narrowness, underdevelopment of the apical bases, and a reduced basal inclination to the anterior cranial base [15].

By comparing the homogeneity of the experimental and control groups, it can be said that these dimensions in the general population are more homogeneous than in the population with hyperdivergent malocclusion class II/1. This again suggests the possibility that a combination of various morphofunctional craniofacial features affects the narrowness of the upper respiratory pathways at least at one level, which is consistent with literary findings, both in studies of the adult and child populations [4, 11, 19, 20, 21].

Another indicator of similarity or differences is obtained by calculating the Mahalanobis distance between the groups of participants. Distances of different spaces can be compared. The distances from the table indicate that the distance between the groups of participants of the experimental group and the control group is greater, and the existing difference is expressed.

In this study, special attention is paid to the impact of inter-jaw relations in the sagittal and vertical dimension (posterior relationship of the lower jaw structures with hyperdivergence of the jaw bases) in children who have not finished growing and can still be therapeutically affected. This, in turn, affects the sagittal narrowness of the upper respiratory pathways. To even consider the connection of these phenomena, it is necessary to define a normal finding.

For skeletal inter-jaw relations, there is an accepted classification of anteroposterior positions (skeletal classes I, II, and III), which is determined by analyzing a standard cephalogram.

Skeletal class II is a disorder of craniofacial development that is treated in children. Correction of morphological abnormalities in children is corrected by properly directing growth, and normalizing the functions of the orofacial muscles, which is achieved by using functional orthodontic devices [22].

Good indicators of the position, both skeletal and soft tissue cranio-cervico-facial structures, are the standard lateral cephalogram, which has been routinely used for many years in the diagnosis of dentofacial anomalies. Researchers like Johal et al., Bittar et al., who examined the reliability of this technique in examining the dimensions of the upper airways, agree that it is competitive as it reveals the most characteristics with the least costs [23, 24], while Pirilä-Parkkinen et al. believe that the precision of measurement with a cephalogram is highest in the region of the nasopharynx and retropalatinal area [25]. However, cone beam computed tomography is being used in computing the functional space of the tongue and surrounding structures. Thus, Xiaoxin Shi et al. found that adults with different OSA types have similar anatomical balance and shape of their upper airway in the supine position [26]. Slowik notes that OSA has significant implications for cardiovascular health, mental illness, quality of life, and driving safety [27].

Given the measured dimensions in the experimental group, both with collectively smaller mean sizes and with significantly smaller mean values for the nasopharynx, oropharynx, and hypopharynx, the hypothesis of this study has been confirmed.

In the adults with developed OSA syndrome, Degraeve finds that MADs may be effective for OSA regardless of whether or not the obstruction site is in the velopharynx or oropharynx [28].

This cross-sectional study is part of a larger longitudinal study in which the effect of orthodontic treatment of hyperdivergent malocclusion of skeletal class II on the dimensions of the upper respiratory pathways was observed.

CONCLUSION

The study showed that the experimental group's upper airways were statistically significantly smaller mean values for the nasopharynx, oropharynx, and hypopharynx, thus confirming the hypothesis of this study.

The measured sagittal dimensions of the upper respiratory pathways in children with hyperdivergent malocclusion class II/1 are significantly smaller than in the general population, at all three observed levels, at the level of the nasopharynx, the level of the oropharynx, and the level of the hypopharynx.

The findings indicate that the upper respiratory pathways in children with hyperdivergent class II/1 are narrower than in the rest of the population, with the greatest difference contributed by narrowness at the level of the oropharynx, less at the level of the nasopharynx, with the smallest contribution at the level of the hypopharynx.

The greater homogeneity of the general population by the value of the widths of the upper respiratory pathways compared to the experimental group indicates the existence of a wide range of possibilities for the adverse effects of morphofunctional disorders of the craniofacial system on the dimensions of the pharyngeal part of the airways.

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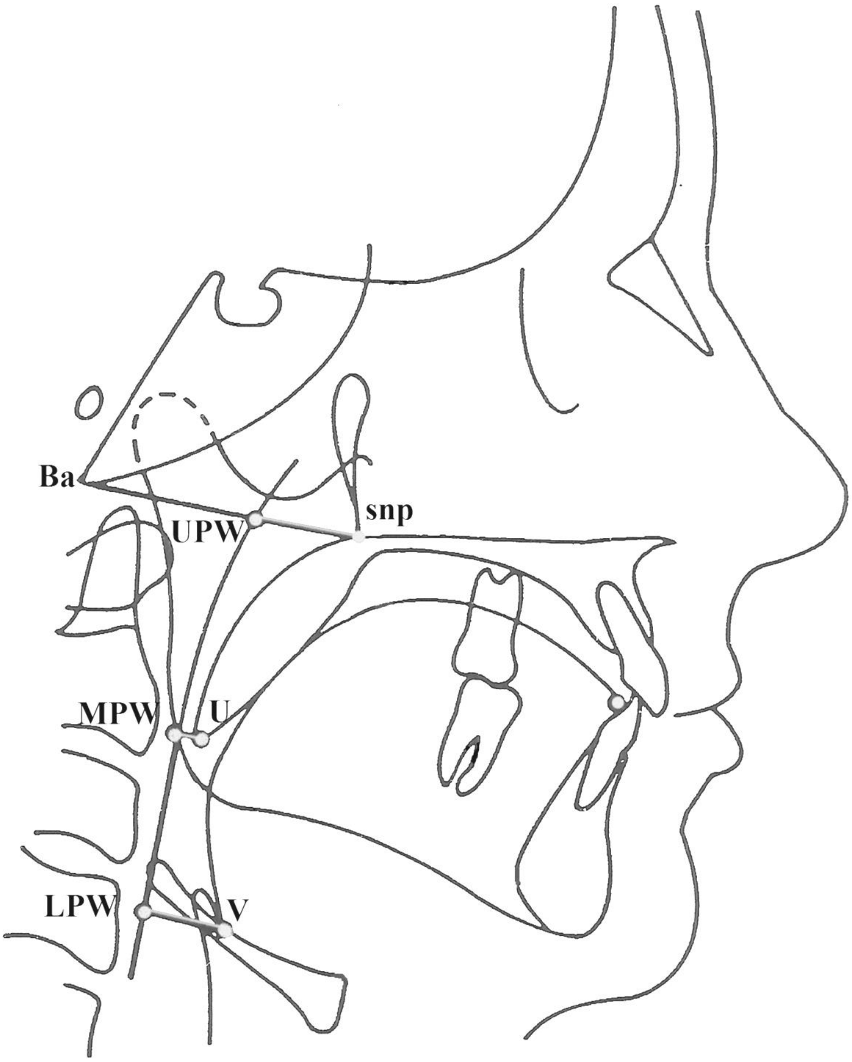

1.

Figure 1. Sagittal diameter dimensions of the upper respiratory pathways

Table 1. Central and dispersion parameters for the dimensions of the upper airways, the experimental group of 31 participants.

Airway segments	Mean value	Standard deviation	Minimal value	Maximal value	Coefficient of variation	Confidence interval		p
Nasopharynx	16.26	3.72	6	23	22.9	14.89	17.62	0.998
Oropharynx	8.19	2.3	3	13	28.08	7.35	9.04	0.884
Hypopharynx	12.03	3.01	6	18	24.98	10.93	13.14	0.976

Table 2. Central and dispersion parameters for the dimensions of the upper airways, the control group of 35 participants

Airway segments	Mean value	Standard deviation	Minimal value	Maximal value	Coefficient of variation	Confidence interval		p
Nasopharynx	19.27	4.18	8.0	29	21.7	17.83	20.71	0.996
Oropharynx	10.33	2.03	6.5	15	19.68	9.63	11.03	0.933
Hypopharynx	13.97	3.27	6.0	24	23.43	12.85	15.1	0.195

Table 3. Significance of differences between participant groups concerning the dimensions of the upper airways (group differences)

Analysis	**n**	**F**	**p**
MANOVA	3	9.085	0.000
Discrimina-tive	3	9.085	0.000

F-value – the significance of the difference in variance between the means of two samples

Table 4. Significance of differences between groups concerning the dimensions of the upper airways (individual differences)

Airway segments	F	p	Discriminant coefficient
Nasopharynx	9.453	0.003	0.176
Oropharynx	16.023	0.000	0.180
Hypopharynx	6.226	0.015	0.017

F-value – the significance of the difference in variance between the means of samples

Table 5. Characteristics and homogeneity of groups concerning the dimensions of the upper airways

Characteristics	Experimental (31)	Control (35)	Contribution (%)
Oropharynx	smaller	larger	48.257
Nasopharynx	smaller	larger	47.185
Hypopharynx	smaller	larger	4.558
SSHE	22/31	28/35	
homogeneity (%)	70.97	80	

SSHE – subsample homogeneity estimates (number of participants with group characteristics compared to total number of group participants)

Table 6. Distance (Mahalanobis) between the groups concerning the dimensions of the upper airways

Group	Experimental	Control
Experimental	0	1.31
Control	1.31	0

